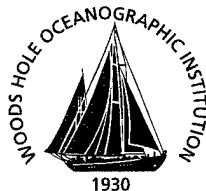


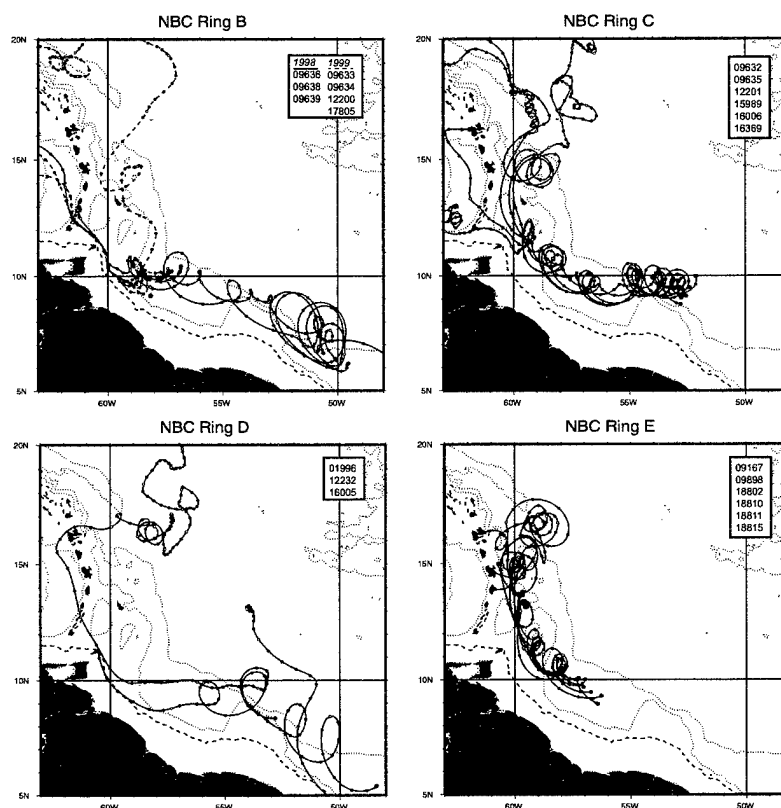
Woods Hole Oceanographic Institution



North Brazil Current Rings Experiment: Surface Drifter Data Report November 1998 – June 2000

by

Deborah A. Glickson, David M. Fratantoni,
Christine M. Wooding, and Philip L. Richardson



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July 2000

Technical Report

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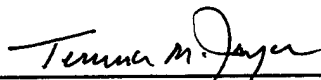
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Terrence M. Joyce, Chair

Department of Physical Oceanography

Abstract

This data report summarizes 45 surface drifter trajectories collected between November 1998 and June 2000 as part of the North Brazil Current (NBC) Rings Experiment. NBC rings have been proposed as one of several important mechanisms for the transport of South Atlantic upper-ocean water across the equatorial-tropical gyre boundary and into the North Atlantic subtropical gyre. Such transport is required to complete the meridional overturning cell in the Atlantic forced by the high-latitude production and southward export of North Atlantic Deep Water. The goal of this program is to obtain, for the first time, comprehensive observations of the NBC retroflexion, the NBC ring formation process, and the physical structure and properties of NBC rings as they translate northwestward along the low-latitude western boundary. A total of 45 drifters were deployed. Twenty-four of these looped anticyclonically within the five rings identified during this experiment. Seven of the looping ring drifters entered the Caribbean, while the rest moved northward along the eastern flank of the Lesser Antilles.

Front Cover Figure Caption: Drifter trajectories for four of the five rings identified by shipboard surveys during the North Brazil Current Rings Experiment.

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1. Introduction

North Brazil Current (NBC) rings are large (400 km diameter) anticyclones that pinch off from the NBC retroflection in the western tropical Atlantic near 8N and translate northwestward along the coast of South America toward the Caribbean (Johns *et al.*, 1990; Didden and Schott, 1993; Richardson *et al.*, 1994; Fratantoni *et al.*, 1995). NBC rings have been proposed as one of several important mechanisms for the transport of South Atlantic upper-ocean water across the equatorial-tropical gyre boundary and into the North Atlantic subtropical gyre. Such transport is required to complete the meridional overturning cell (MOC) in the Atlantic forced by the high-latitude production and southward export of North Atlantic Deep Water. The mechanisms that contribute to NBC ring formation and the structure and dynamics of the rings themselves are not well understood. The purpose of this study is to obtain, for the first time, comprehensive observations of the NBC retroflection, the NBC ring formation process, and the physical structure and properties of NBC rings as they translate northwestward along the low-latitude western boundary. The goal is to understand the process of NBC ring generation and to quantify the role of NBC rings in cross-equatorial and cross-gyre transport within the Atlantic MOC. Specific objectives of the drifter component of the NBC Rings Experiment are to:

1. Measure and describe the physical structure of NBC rings after separation from the NBC, including both near-synoptic and time-evolving temperature and velocity characteristics.
2. Determine characteristic rates of translation, mixing, and decay as NBC rings move northwestward toward the Caribbean Sea.
3. Identify the long-term fate of South Atlantic water trapped within the ring core, and determine the effective intergyre ring transport in several temperature/density watermass classes.

A total of 45 drifters was launched from R/V Seward Johnson during three NBC Rings Experiment survey cruises (Figure 1 and Table 1). Ten drifters were provided by WHOI and 35 were provided by AOML. Five NBC rings were identified during the three cruises. Twenty-four drifters were launched in these rings. Subsurface RAFOS floats (not described here) were also launched to track the rings and observe their evolution.

Table 1. Number of drifters launched during each cruise.

Cruise	Beginning Date	Ending Date	Drifters Launched	
			<i>Total</i>	<i>Into Rings</i>
NBC 98	11-07-98	12-11-98	16	5
NBC 99	02-06-99	03-09-99	16	13
NBC 00	01-29-00	02-24-00	13	6

2. Description of the Drifters

The surface drifters used in this study are similar in construction to the World Ocean Circulation Experiment (WOCE) and Tropical Ocean-Global Atmosphere (TOGA) Lagrangian drifters described by Sybrandy and Niiler (1991). The drifter consists of a spherical surface float 35 cm in diameter, a 0.56 cm diameter plastic impregnated wire tether

with a 20 cm diameter subsurface float located 275 cm below the surface, and a 644 cm long cylindrical cloth drogue (92 cm diameter) with circular holes in its sides. The fiberglass surface float contains a radio transmitter, batteries, antenna, and sensors including a thermometer and strain gauge sensor that indicates whether or not the drogue is attached. The drogue is centered at a depth of 15 m. The ratio of the drag area of the drogue to the drag area of the tether and float is approximately 41:1, which results in the drogue's slip through the water being less than 1 cm/sec in winds of 10 m/sec (Niiler *et al.*, 1995).

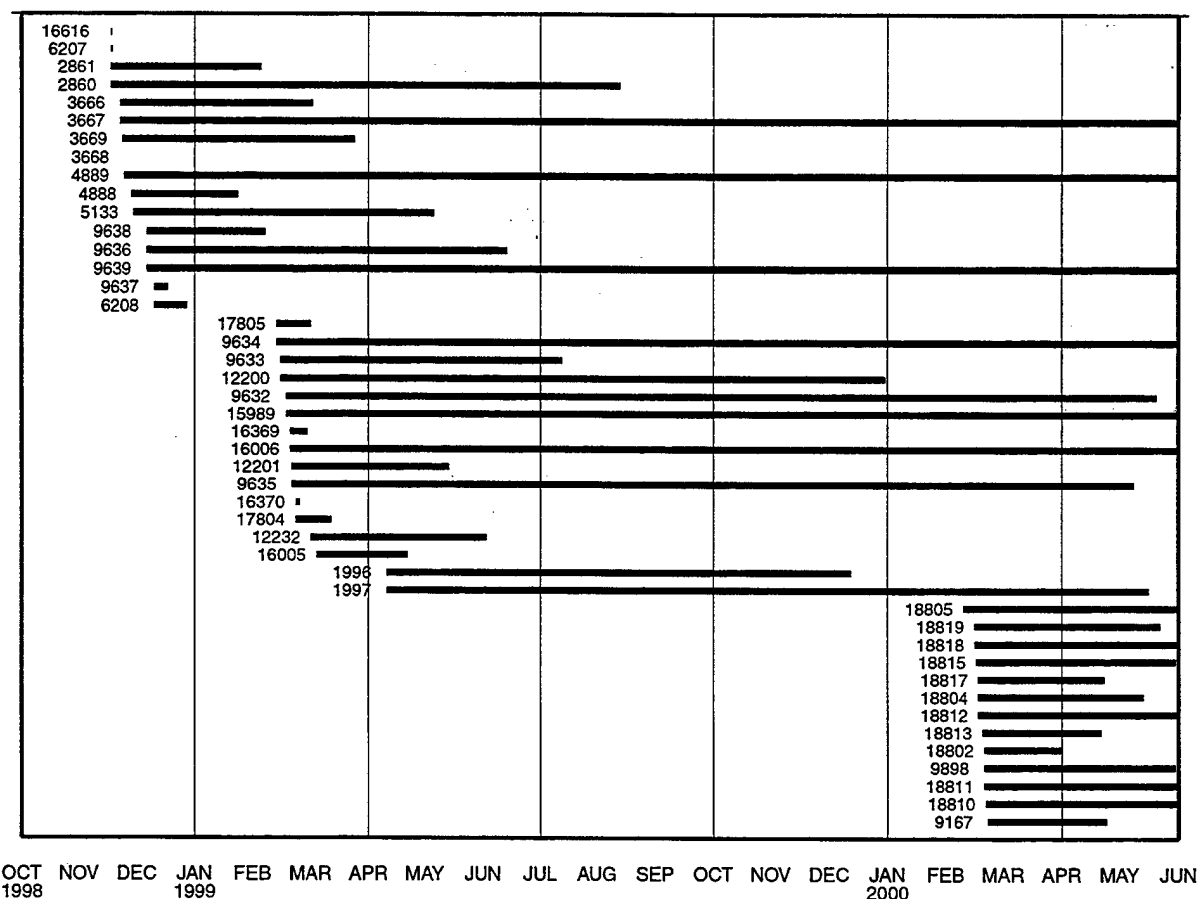


Figure 1. Surface drifter duration chart. Drifter numbers are shown to the left of the black line that indicates lifespan. Drifters are listed in order of launch date.

3. Drifter Deployment

To choose suitable locations for drifter and subsurface float deployment, each cruise began by mapping the upper-ocean temperature and velocity structure using expendable bathythermographs (XBTs) and a shipboard ADCP. This enabled a determination of each ring's center, overall shape and intensity. Surface drifters were then deployed to measure the circulation in and around NBC rings as they translate and evolve. A single drifter was also used to track Ring E's westward translation between consecutive legs of the third cruise.

4. Drifter Performance

Table 2 lists the launch and end positions for each drifter, as well as its lifetime. The average lifetime of the NBC drifters up to June 1, 2000 was 168 days. Of the 45 drifters, 7 stopped transmitting within a month. As of June 1, 2000, 9 were still drifting and actively transmitting.

5. Drifter Data Processing and Tracking

Service Argos satellites forwarded the surface drifter positions and transmissions to WHOI via email. At least five data messages had to be received in one pass for the drifter position to be computed by Argos. Position errors are estimated to be around 300 m. The most frequently transmitted data message in a pass was used for temperature, drogue, and voltage values at each location. Coefficients for conversion of raw data to engineering units were provided by AOML. The data were linearly interpolated at a six-hour spacing to produce four records per day. A two-day half-width Gaussian filter (Figure 2a) was applied to suppress tidal and inertial variability. A comparison of the unfiltered and filtered data is shown in Figure 2b. Velocities were computed from the filtered position time series using a cubic spline function. Temperature measurements were filtered by removing data points more than 3 standard deviations from the mean, then taking a two day running mean of the remaining data.

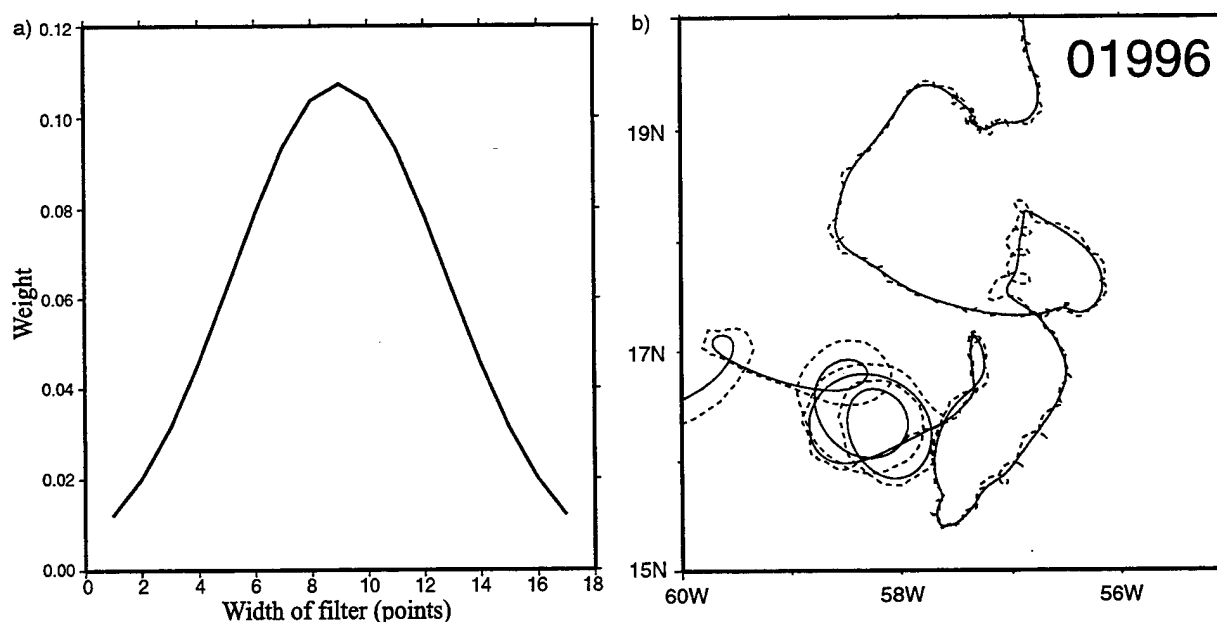


Figure 2. a) The two-day half-width Gaussian filter used for smoothing drifter position and time series data. b) A blow-up of drifter 01996's trajectory showing the interpolated (dashed line) and filtered data (solid line). The loops near 16N, 58W were in an eddy with a period of approximately 14 days. The smaller loops near 18N, 57W are inertial oscillations with a period of approximately 2 days.

Table 2. Surface drifter summary – launch and end positions.

Drifter ID	Launch Date	Launch Position		End Position		Life (days)	Drogue off (date)	Grounded (date)	Launched in Ring
		Lon.	Lat.	Lon.	Lat.				
01996	990411	-52.796	8.340	-59.158	23.927	245			D
01997	990411	-52.161	8.318	-19.631	1.795	401			
02860	981117	-49.818	9.160	-57.569	23.556	269			
02861	981117	-51.463	9.838	-61.379	14.633	79	990204		
03666	981122	-45.777	6.733	-58.765	8.463	101			
03667	981122	-47.519	7.117	-59.531	22.517	556*			
03668	981124	-47.204	3.152	-47.423	3.439	1			
03669	981123	-46.504	4.327	-45.955	13.048	122			
04888	981128	-47.755	2.164	-53.969	12.250	56			
04889	981124	-45.897	5.041	-61.231	14.809	554*	990516	990320	
05133	981129	-49.387	6.379	-50.570	11.660	158			
06207	981112	-52.091	10.915	-52.091	10.915	0			
06208	981210	-56.389	9.216	-57.648	8.415	17			A
09167	000220	-57.252	10.088	-59.460	13.163	62		000324	E
09632	990217	-52.716	8.952	-71.641	22.531	458			C
09633	990214	-57.528	10.039	-67.166	18.460	149		990611	B
09634	990212	-56.842	10.486	-78.406	27.691	474*			B
09635	990220	-52.328	9.554	-64.690	38.729	443			C
09636	981206	-50.569	6.506	-61.245	12.988	190		990317	B
09637	981210	-56.263	8.851	-56.673	9.307	7			A
09638	981206	-49.536	6.211	-41.048	8.003	62			B
09639	981206	-50.030	6.306	-63.944	27.771	542*			B
09898	000220	-56.657	9.469	-60.903	14.618	100*		000403	E
12200	990214	-57.223	10.246	-79.860	19.705	319		990908	B
12201	990220	-52.190	10.034	-61.815	16.262	83	990513	990514	C
12232	990302	-48.357	5.466	-60.532	11.294	94	990531	990526	D
15989	990217	-52.734	9.029	-86.104	29.329	469*			C
16005	990305	-47.312	2.986	-53.884	13.010	48			D
16006	990219	-52.579	8.741	-64.518	25.844	467*			C
16369	990219	-52.432	9.140	-53.687	9.100	9			C
16370	990222	-51.721	6.133	-51.743	6.934	2			
16616	981111	-51.123	12.990	-51.123	12.990	0			
17804	990222	-51.595	6.155	-55.902	10.849	19			
17805	990212	-56.846	10.258	-58.189	9.073	18			B
18802	000220	-57.016	9.642	-60.653	14.977	40	000317		E
18804	000217	-55.381	9.416	-46.053	10.409	86			
18805	000209	-55.258	9.187	-44.259	16.930	112*			
18810	000221	-56.992	10.055	-58.191	17.011	100*			E
18811	000220	-56.232	9.332	-61.353	16.333	101*	000328	000416	E
18812	000217	-55.046	9.725	-47.362	11.692	104*			
18813	000219	-55.783	9.280	-49.801	9.441	62			
18815	000216	-56.249	8.862	-60.889	13.913	104*	000510	000510	E
18817	000217	-55.768	9.191	-59.475	13.175	66	000305	000415	
18818	000215	-55.422	9.264	-48.734	14.406	106*			
18819	000215	-55.419	9.261	-46.368	13.147	97			

* still alive as of June 1, 2000

6. Acknowledgments

The assistance of the captain and crew of the R/V Seward Johnson is gratefully acknowledged. We thank the participants of the three NBC Ring cruises for their assistance in launching drifters. Thirty-five drifters were provided for launch by the Global Drifter Center of NOAA/AOML. We thank Mark Swenson, Doug Wilson, and Silvia Garzoli for their cooperation in acquiring, deploying, and tracking these drifters. Financial support for this research program was provided by the National Science Foundation through Grant No. OCE-9729765.

7. References

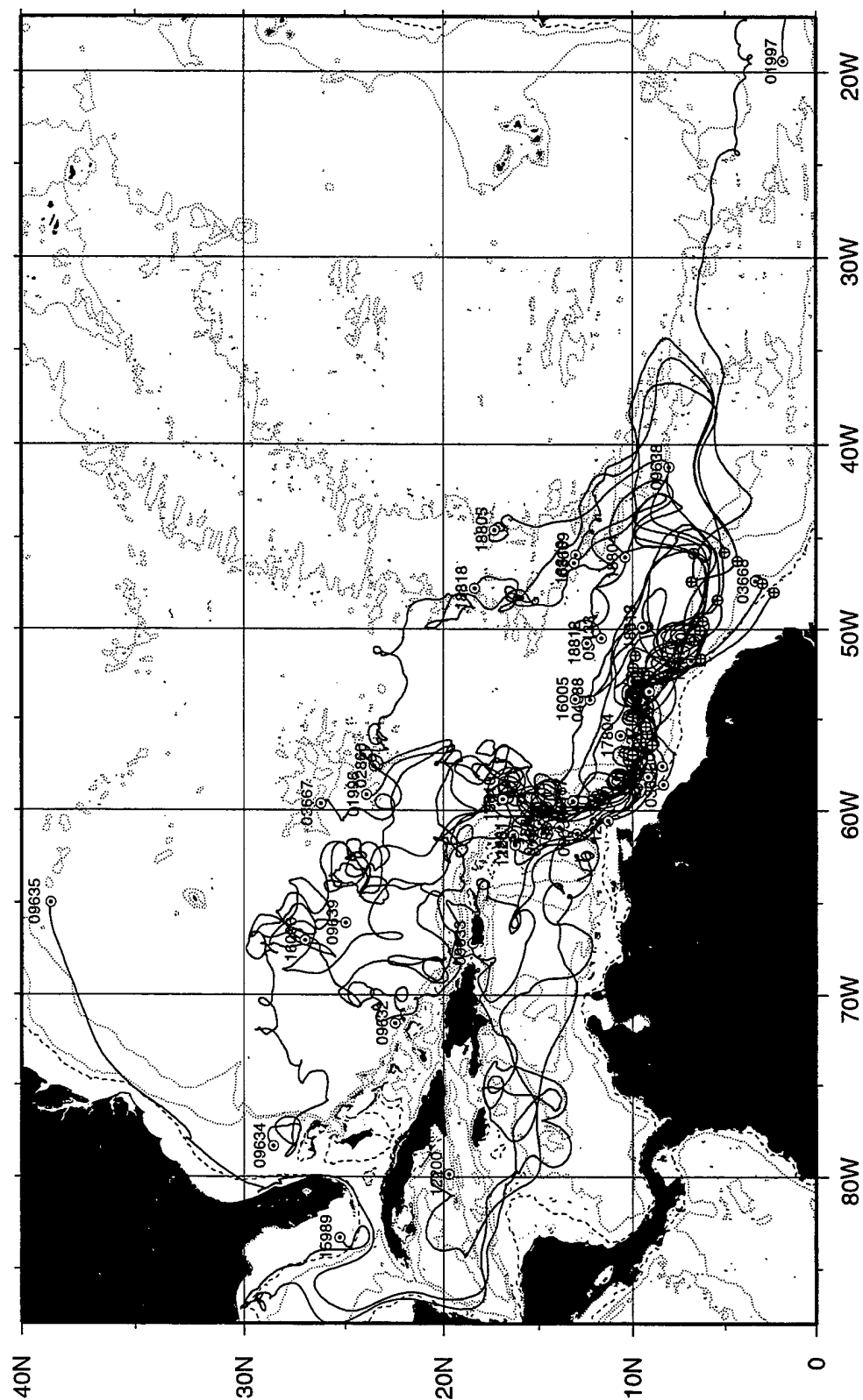
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Appendix A:

Drifter displacements and trajectories.

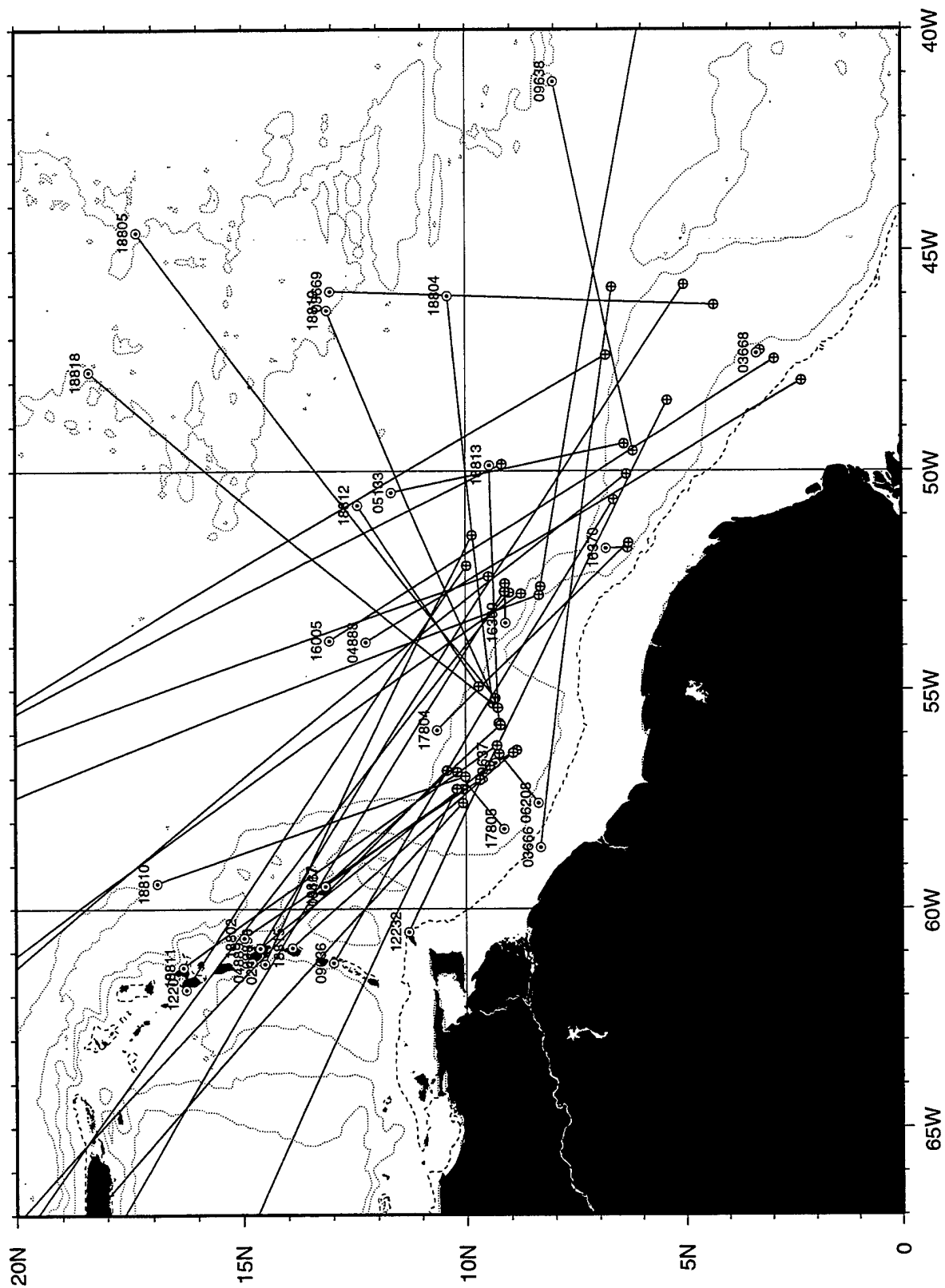
The following figures present drifter vector displacements and trajectories for all drifters launched in the NBC Rings Experiment. Launch positions are marked with a plus sign and end positions with a circle-dot symbol and the drifter ID. Drifter tracks are solid black lines. A dashed line represents the 200 m isobath, and dotted lines are isobaths in 2000 m increments. Both the displacements and trajectories are shown first at a small-scale, encompassing most of the drifter trajectories, and then at a larger scale, showing only the Caribbean and NBC area.

Composite of All NBC Surface Drifter Trajectories



[illegible]

Expanded View of Displacement Vectors

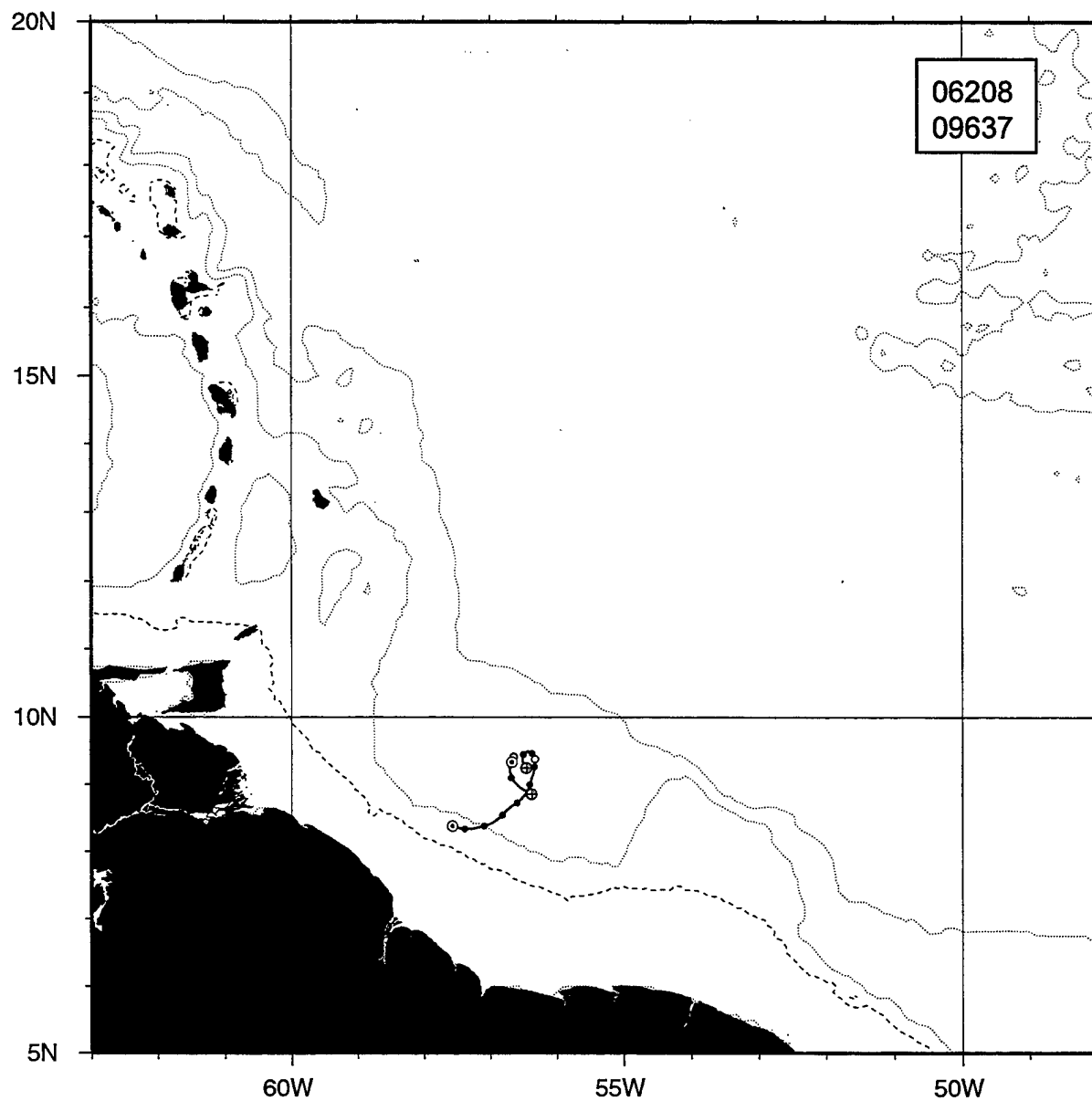


Appendix B:

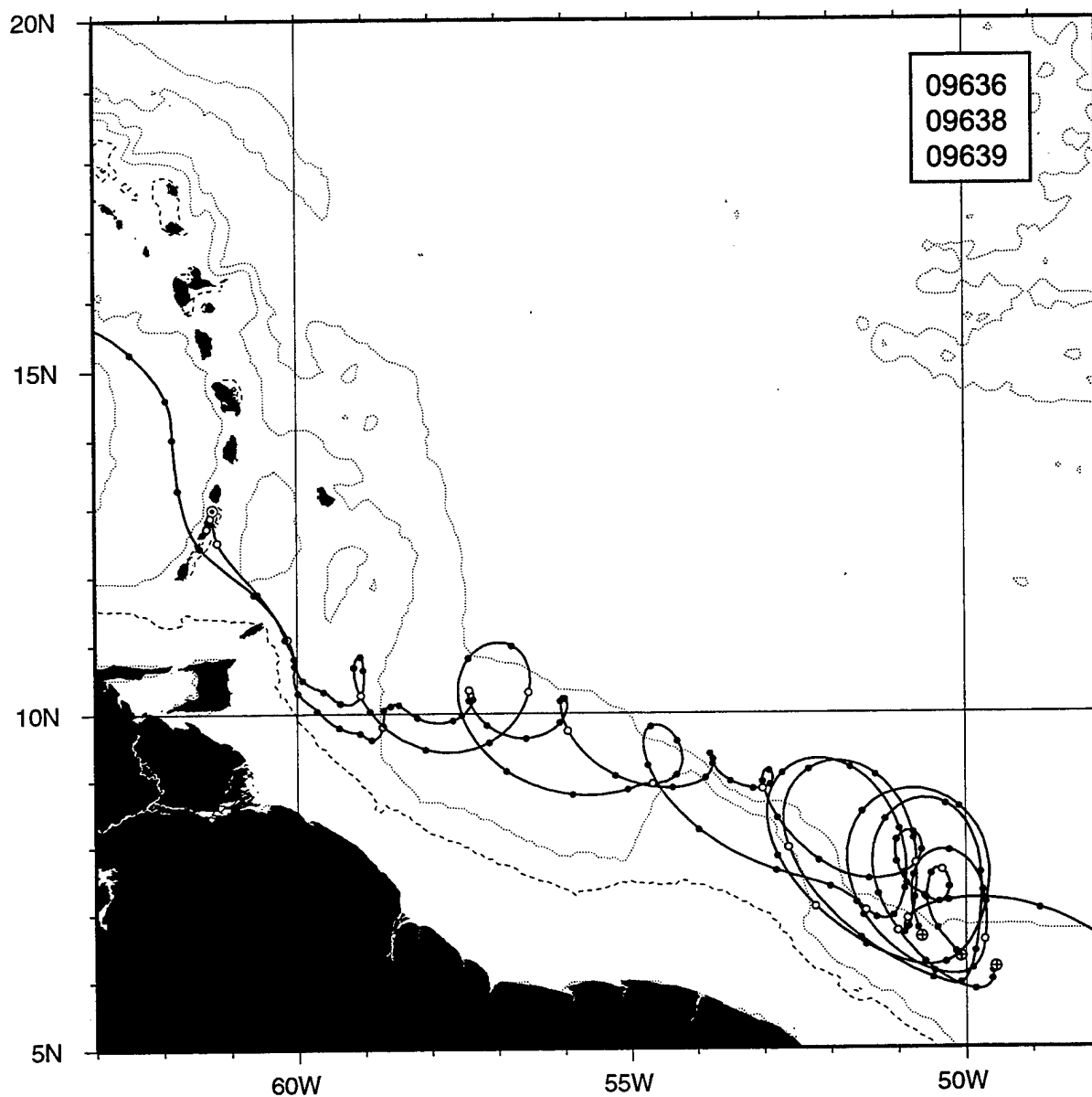
Drifter trajectories within rings.

This section presents diagrams of the drifter trajectories for each ring identified in this study. Time ticks (small filled circles) are shown every two days, and the date ('yymmdd') is appended to small open circles on the first and fifteenth day of each month (unless removed for clarity). Individual drifter trajectories are not labeled, but a list of drifters shown is provided in the upper right-hand corner of each figure. Drifter launch and end positions are marked as in Appendix A, as are isobaths. Drifter tracks are solid black lines, unless indicated otherwise.

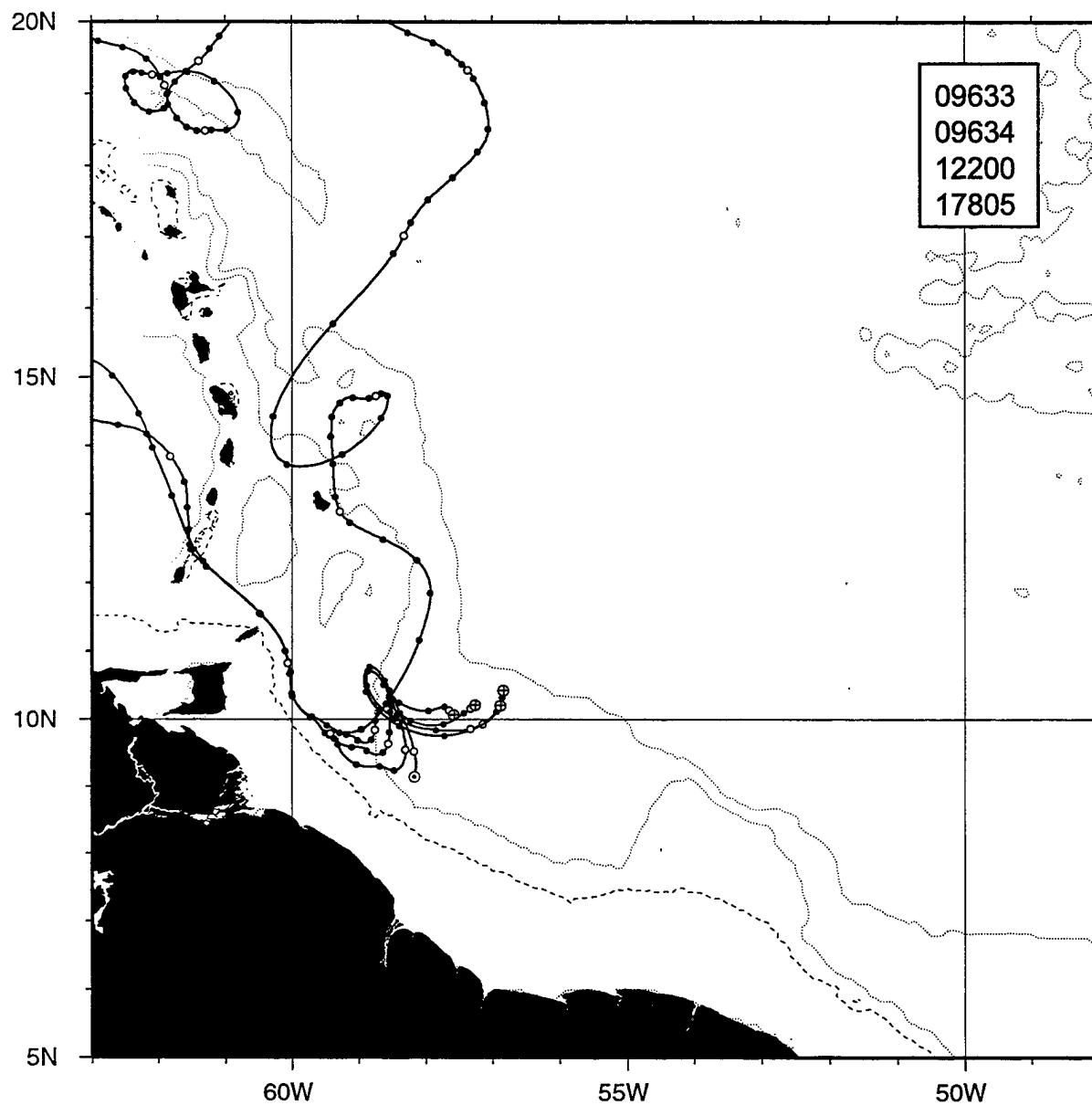
Drifters launched into NBC Ring A, 1998



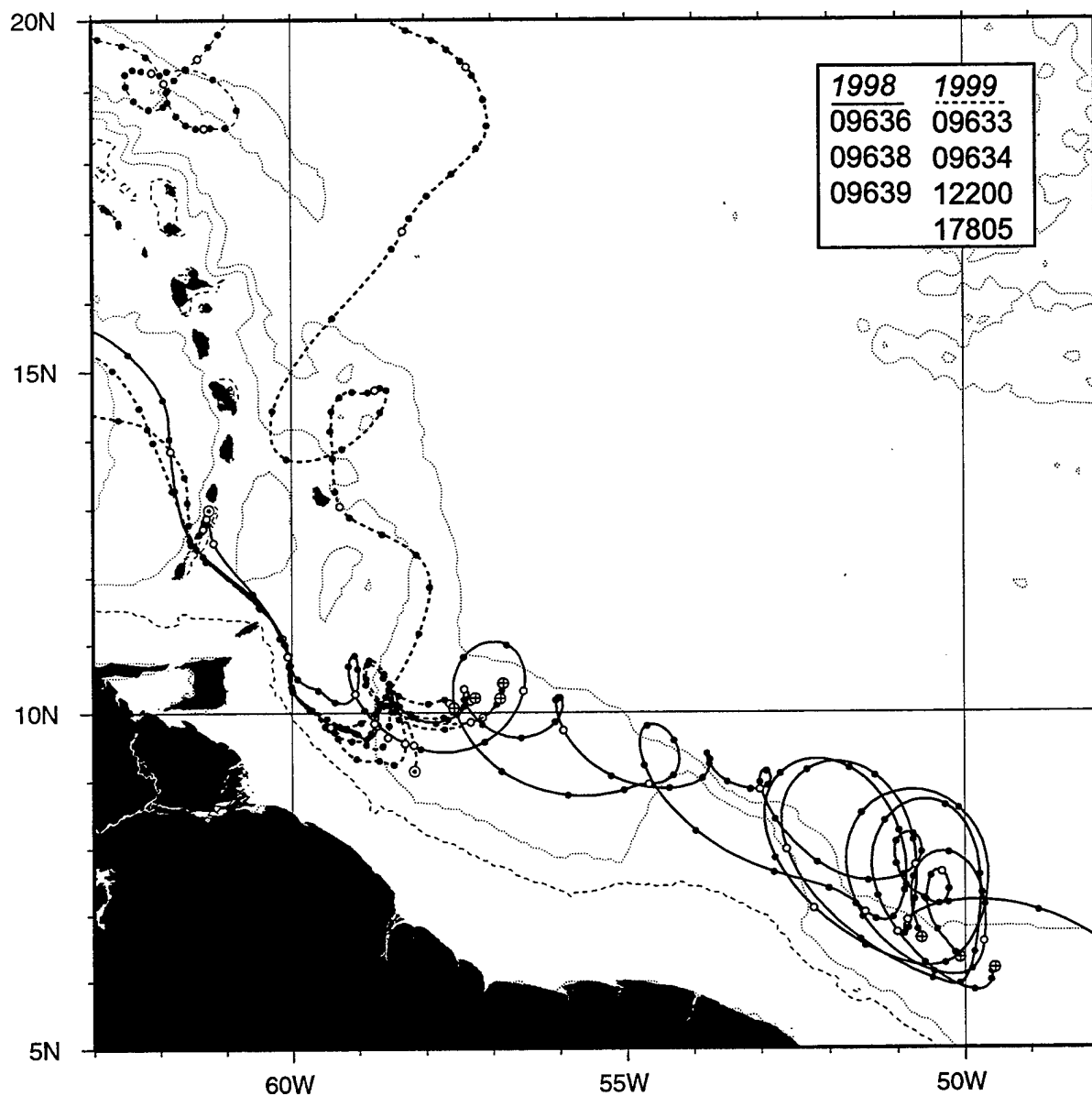
Drifters launched into NBC Ring B, 1998



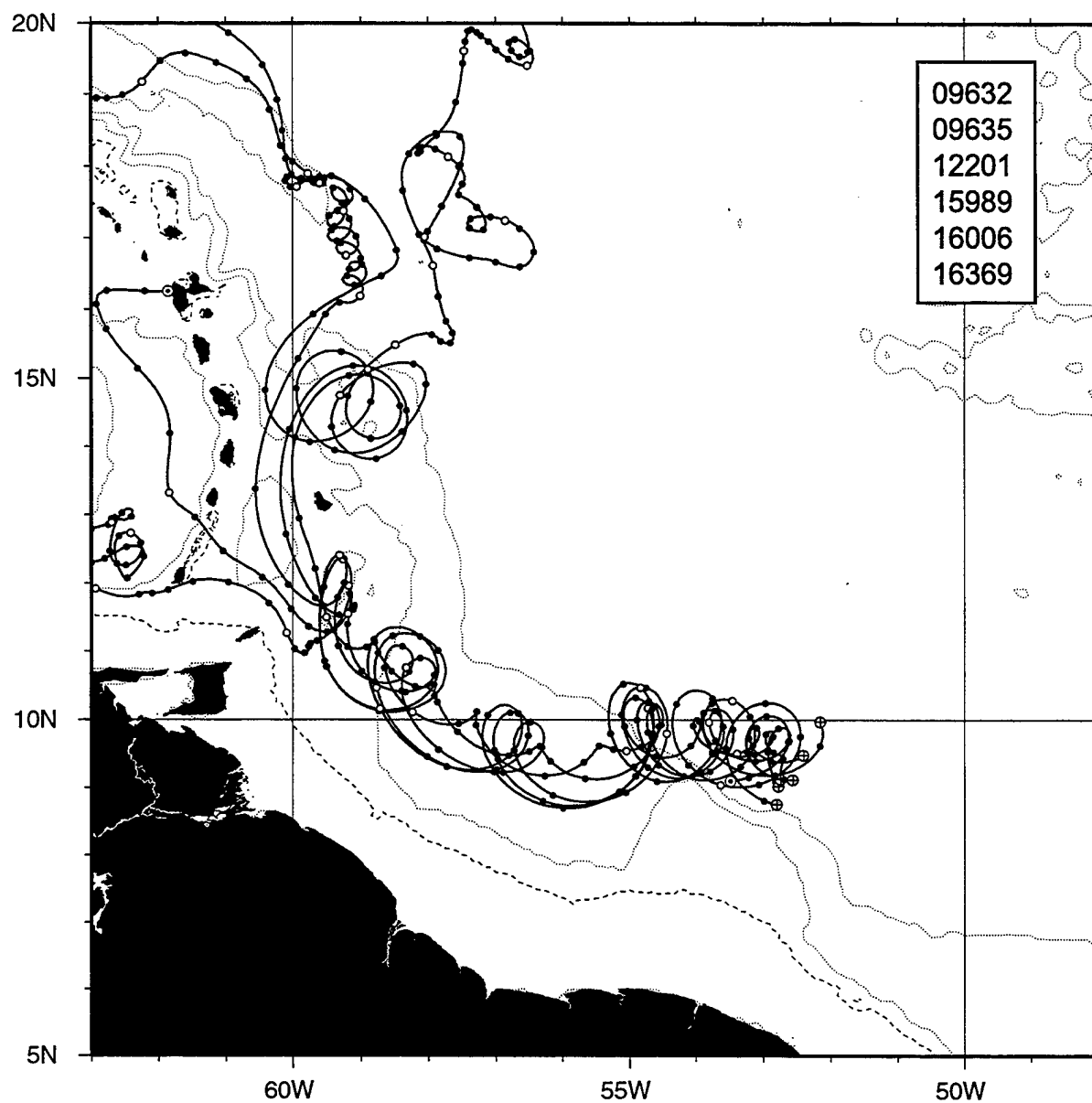
Drifters launched into NBC Ring B, 1999



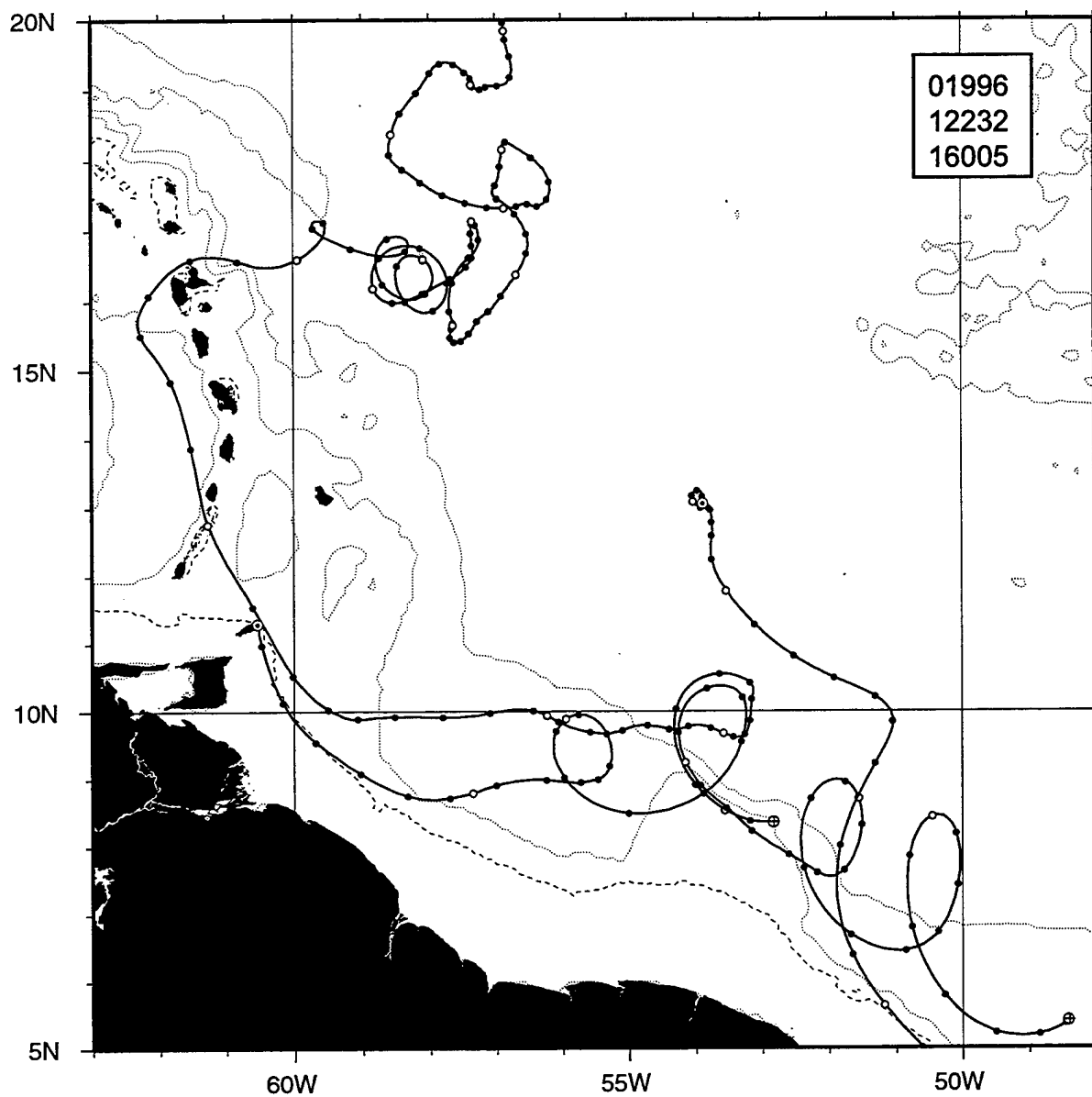
Drifters launched into NBC Ring B, 1998 and 1999



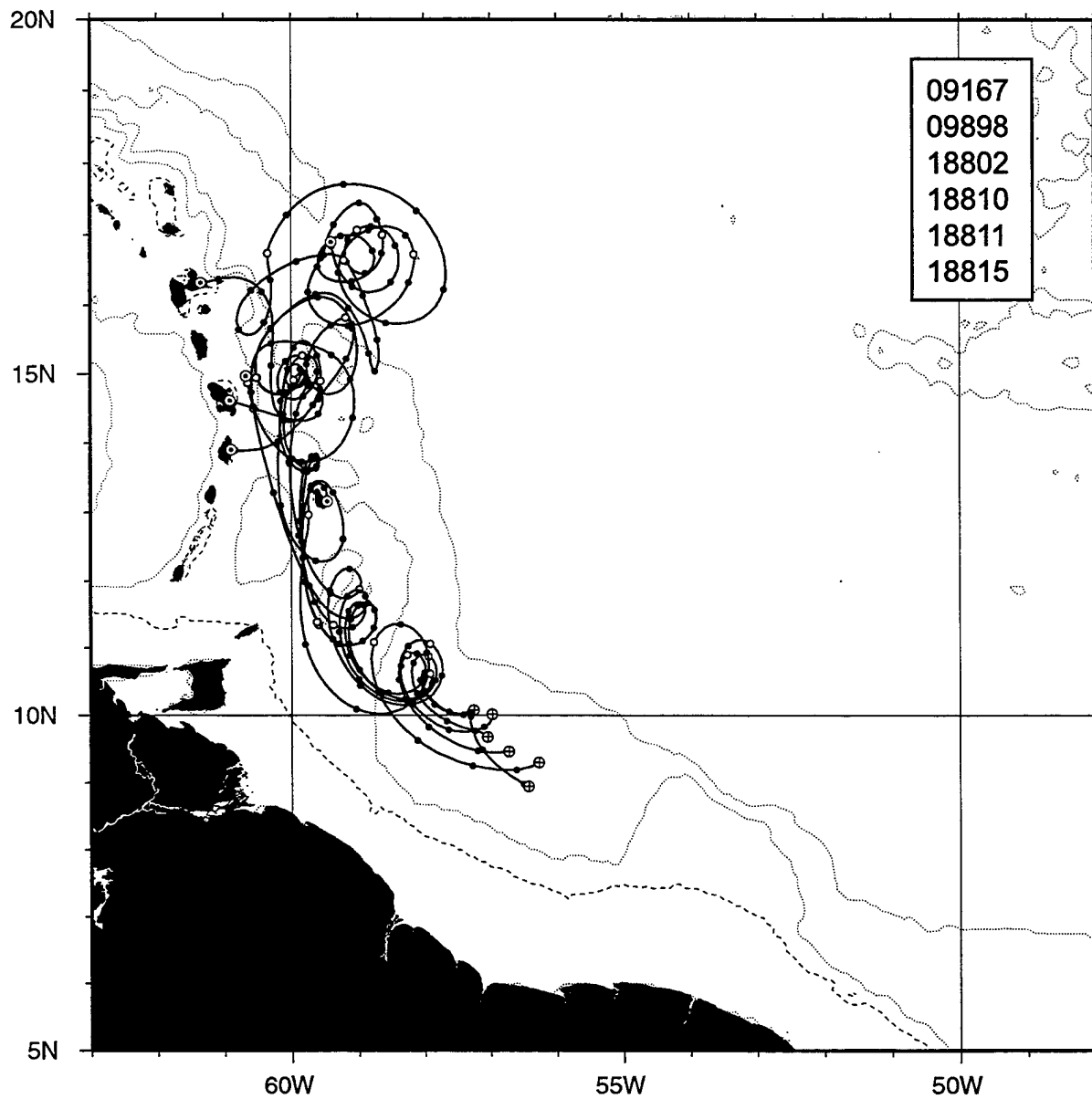
Drifters launched into NBC Ring C, 1999



Drifters launched into NBC Ring D, 1999



Drifters launched into NBC Ring E, 2000

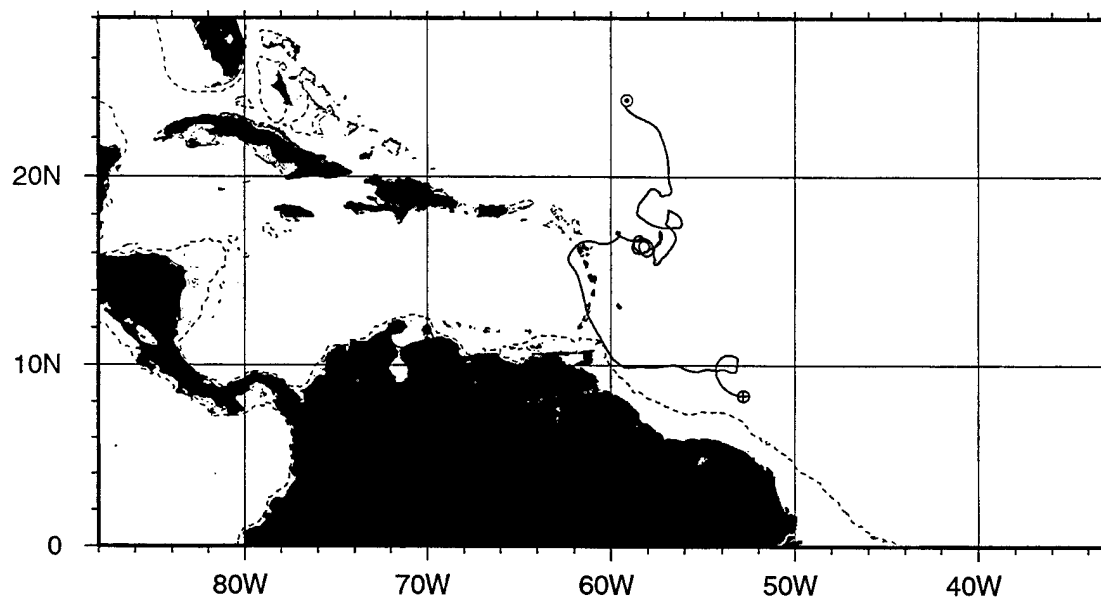
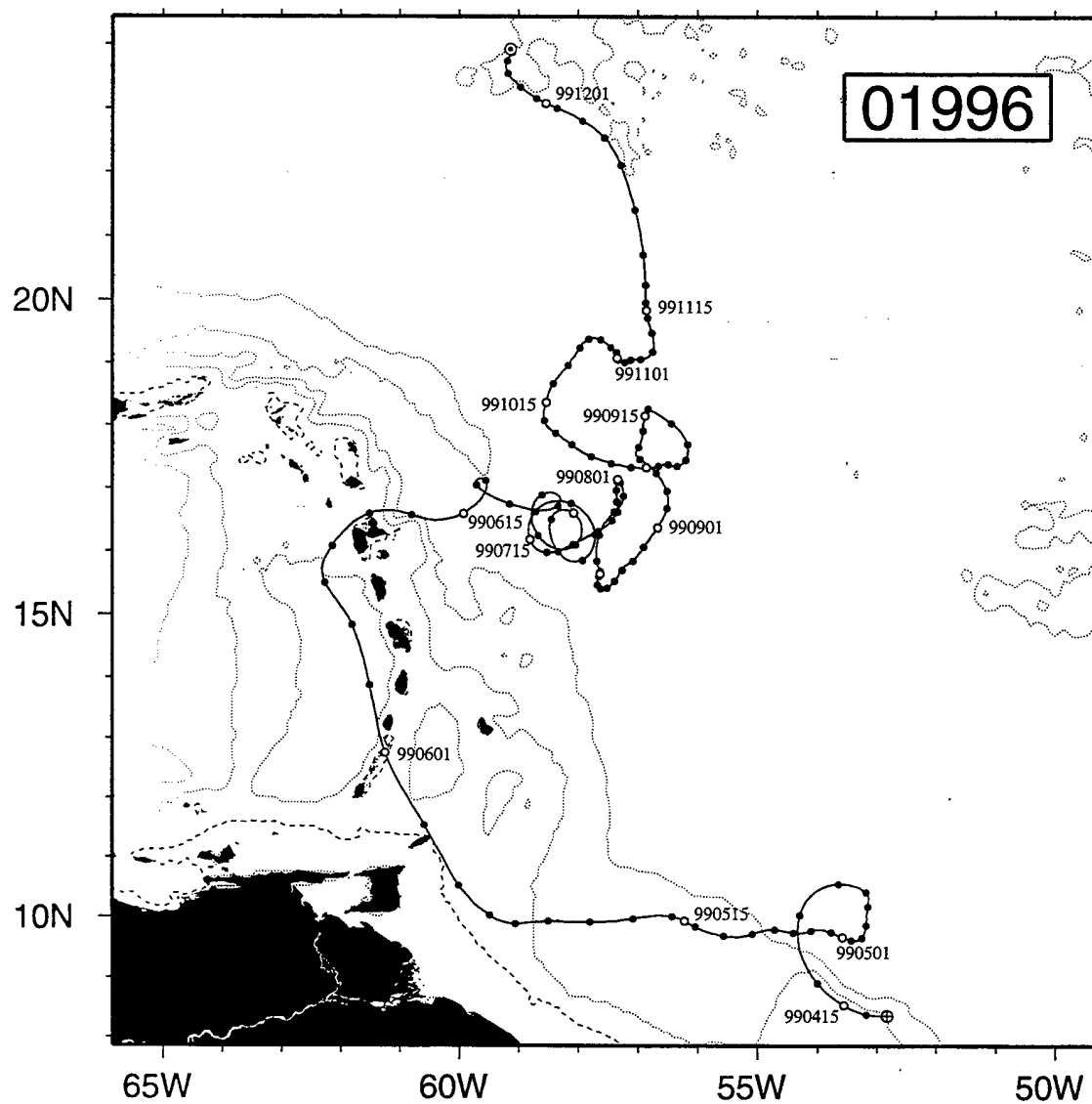


Appendix C:

Individual drifter tracks and drifter property plots.

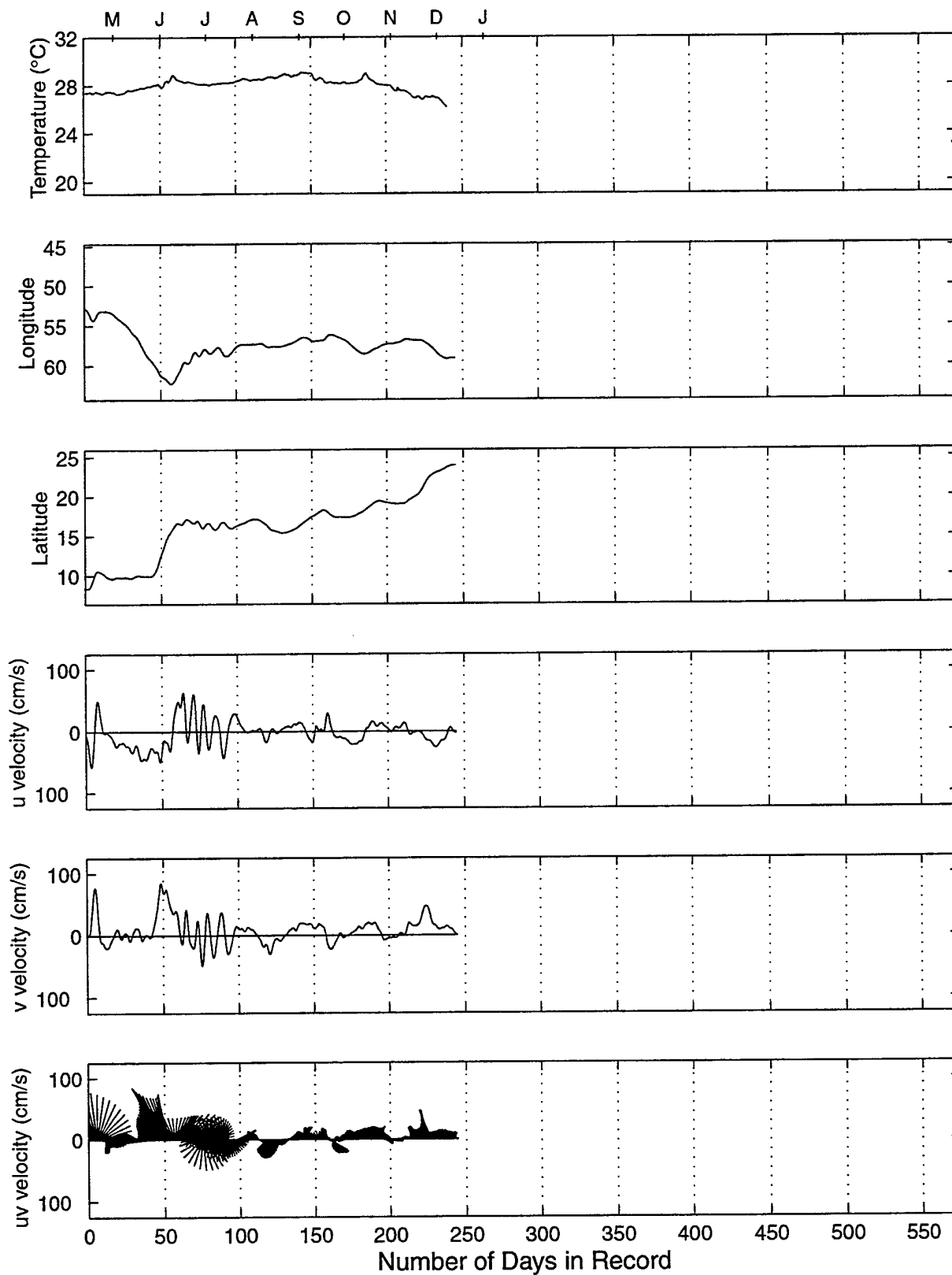
The following section presents individual drifter trajectories and temperature, position, and velocity time series measurements. The trajectories are presented at a large, flexible scale (top) to show detail, and at a fixed scale (bottom) for comparison to other drifters in and around the study area. All features are marked as in Appendices A and B, although time ticks and isobaths (except at 200 m) have been omitted from the fixed scale plots.

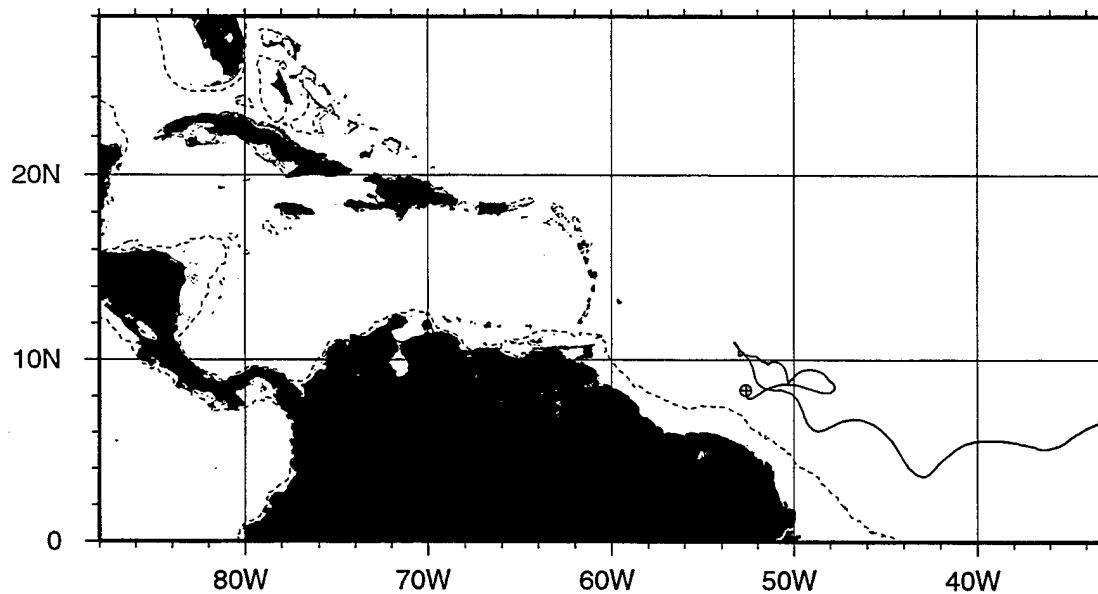
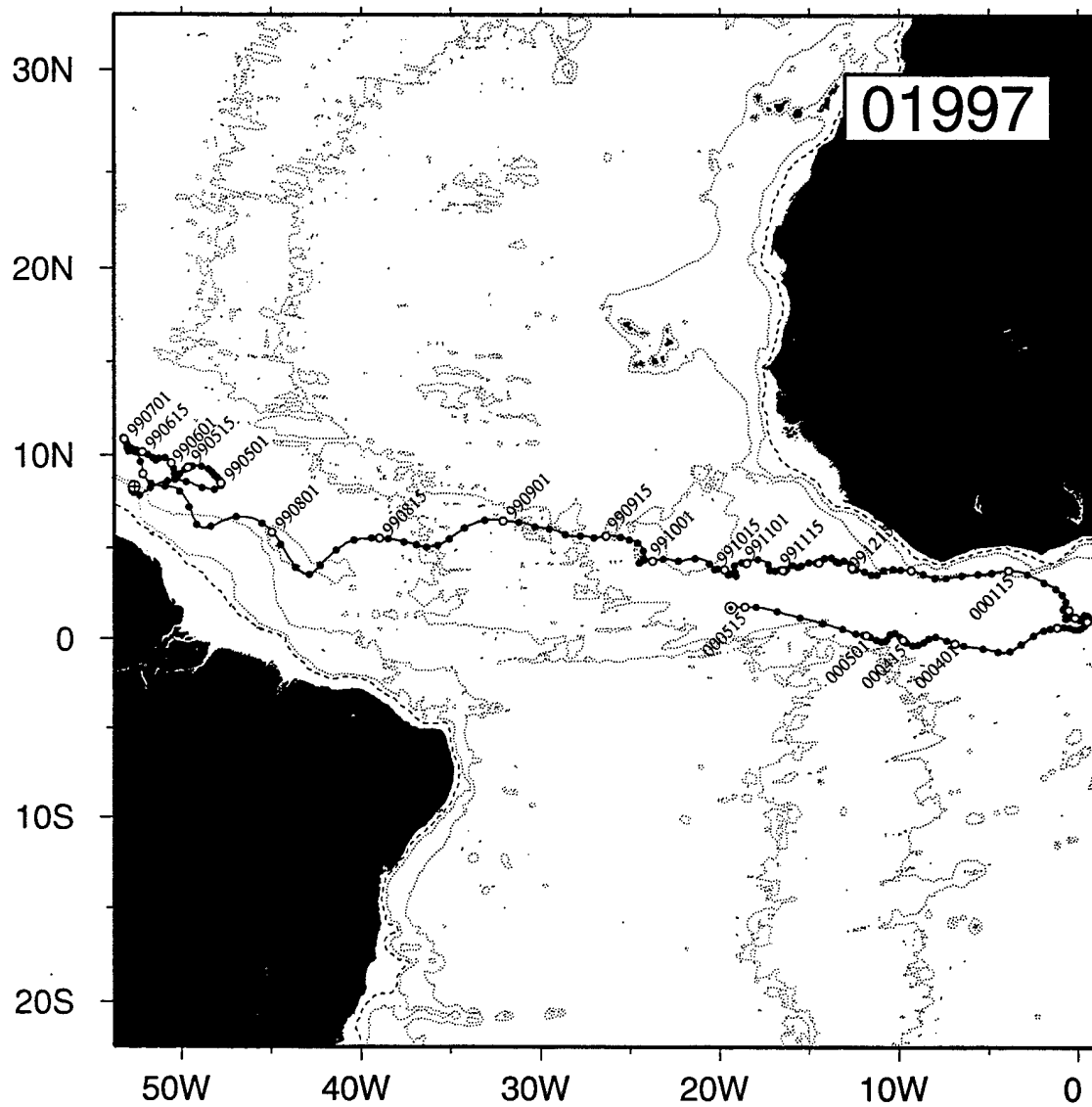
Drifter property plots show temperature, longitude, latitude, u (east) velocity, v (north) velocity, and velocity stick diagrams. The lower x-axis marks the number of days in the drifter record. Measurements were interpolated to six hour intervals. Temperature measurements were filtered by removing data points more than 3 standard deviations from the mean, then taking a two day running mean of the remaining data. The upper x-axis shows a Gregorian calendar corresponding to the record day in the lower x-axis. Thin double lines mark the day where the drogue fell off before the drifter stopped transmitting.



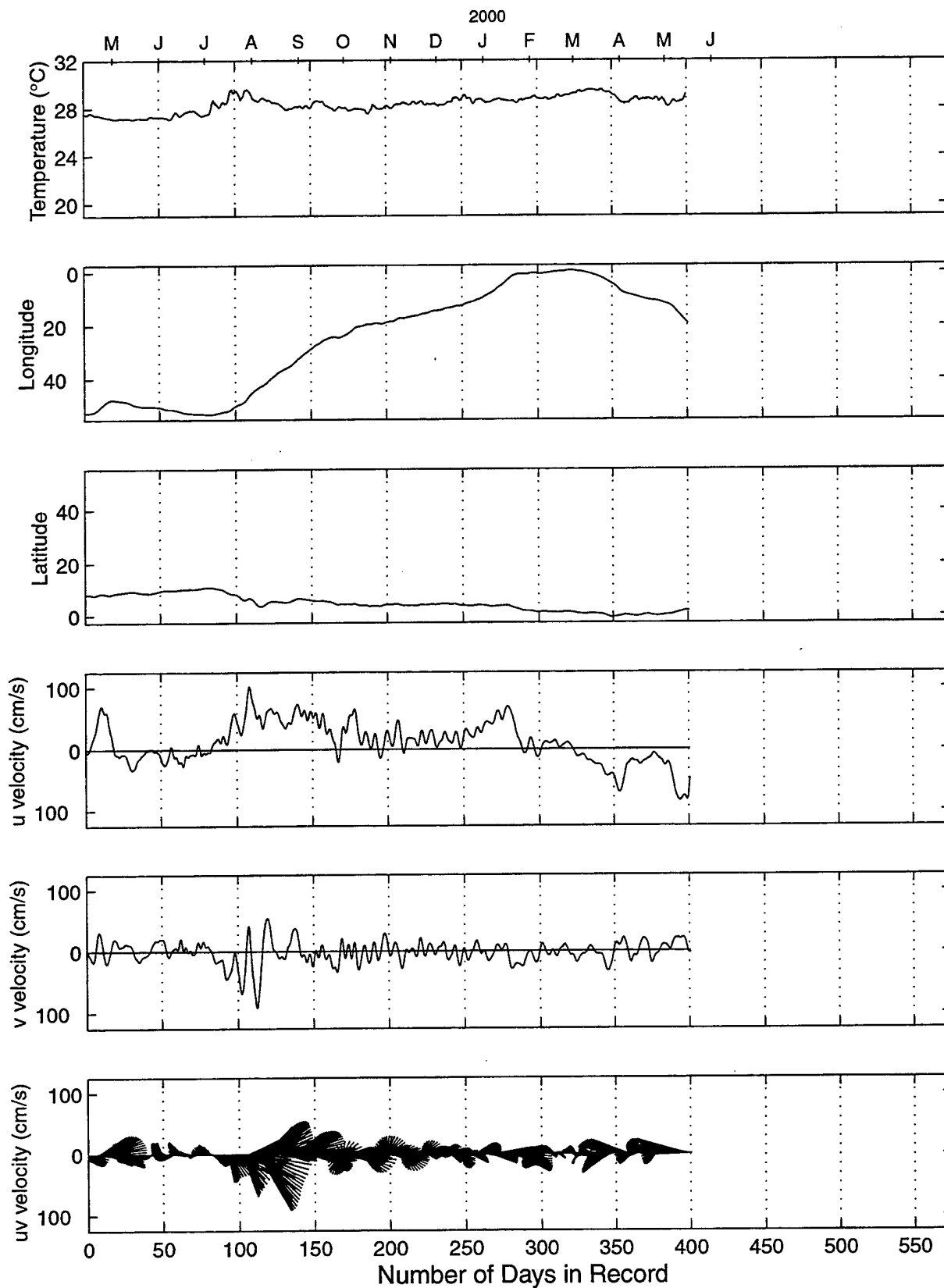
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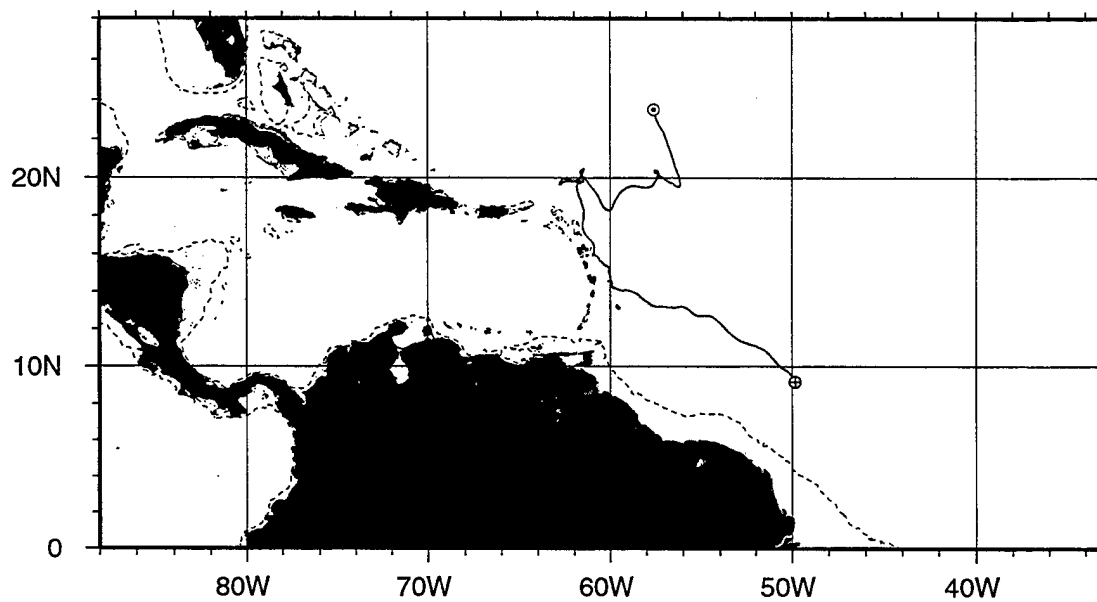
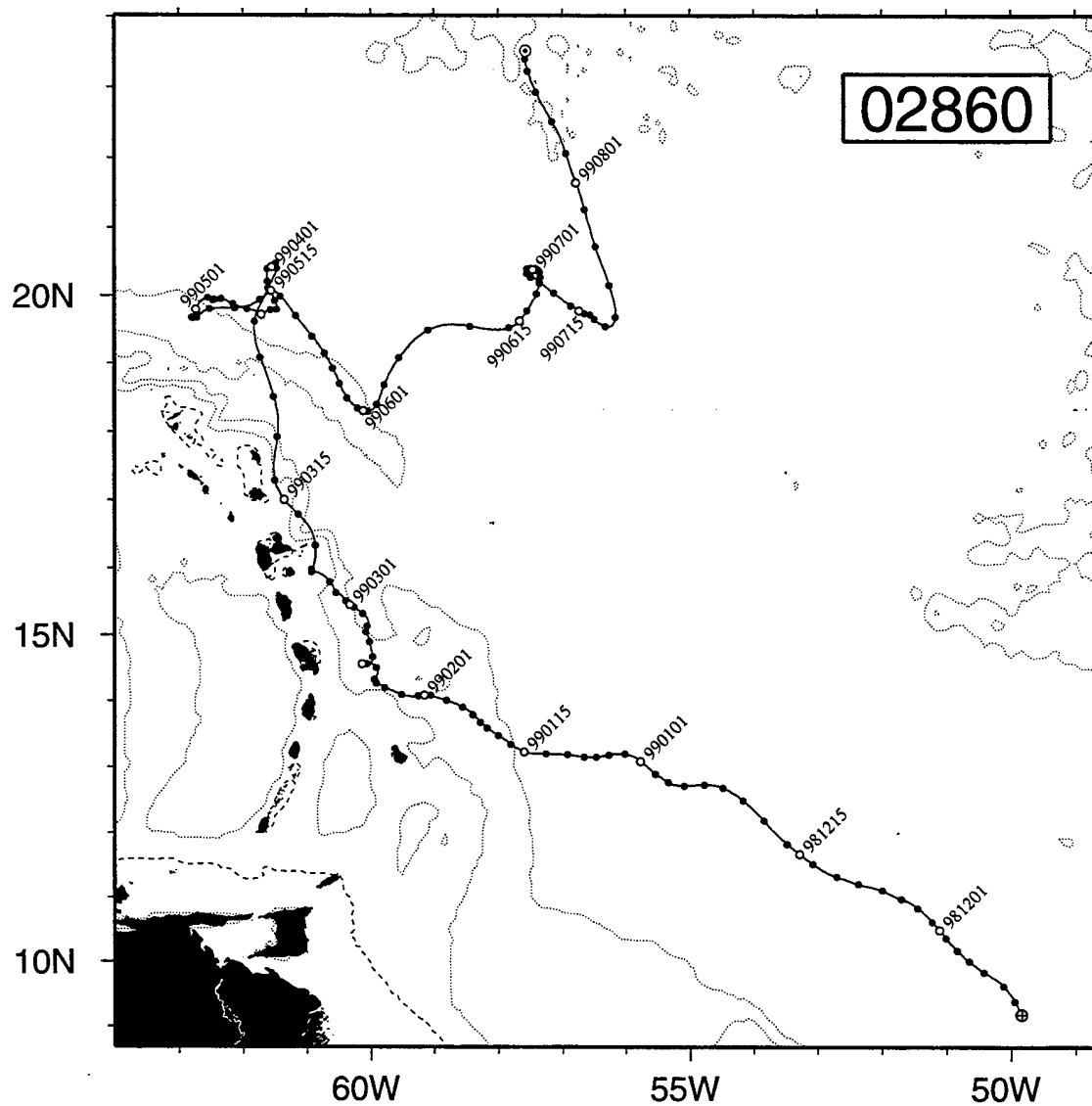
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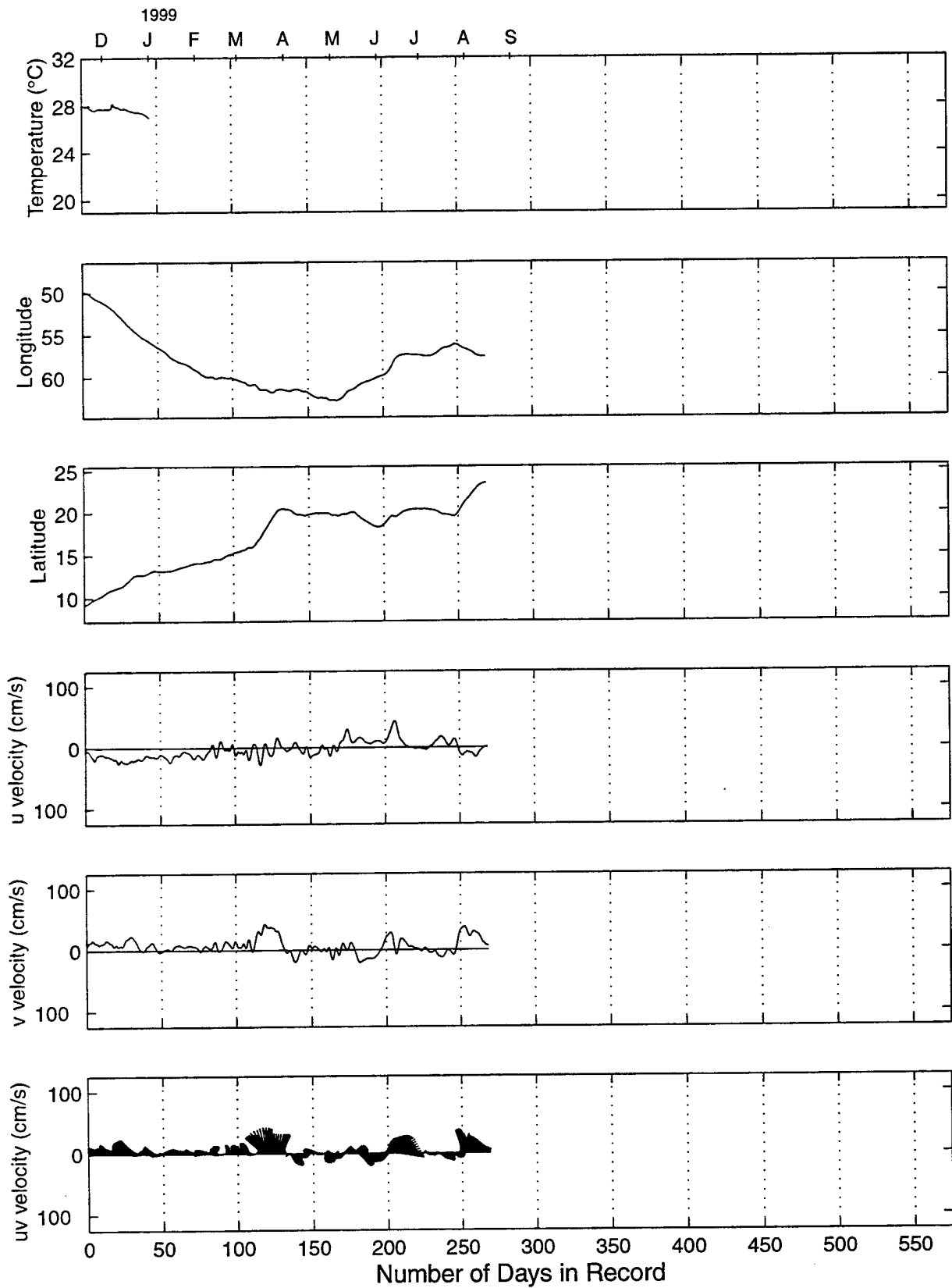


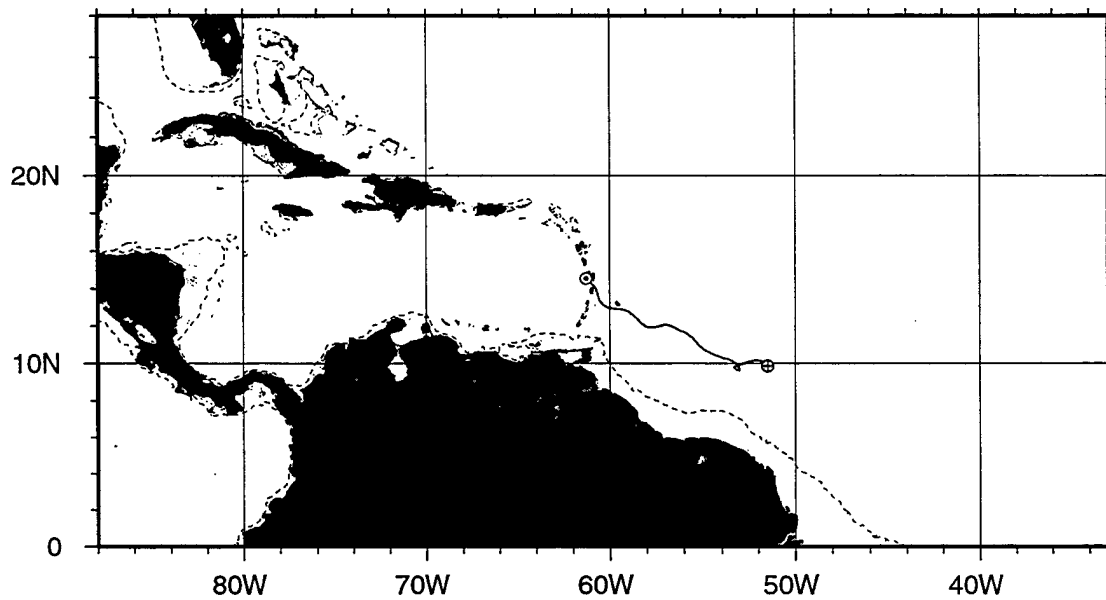
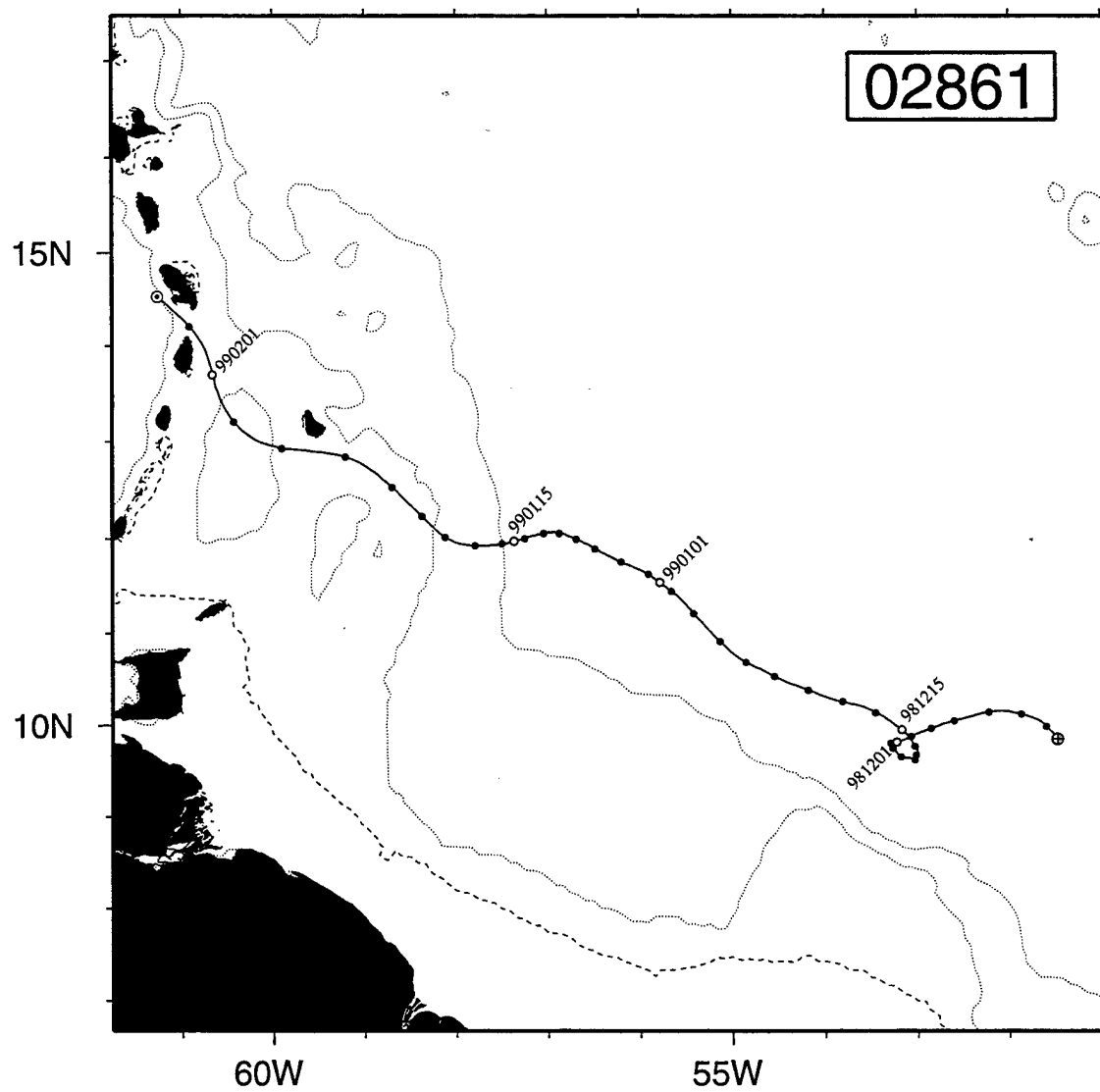
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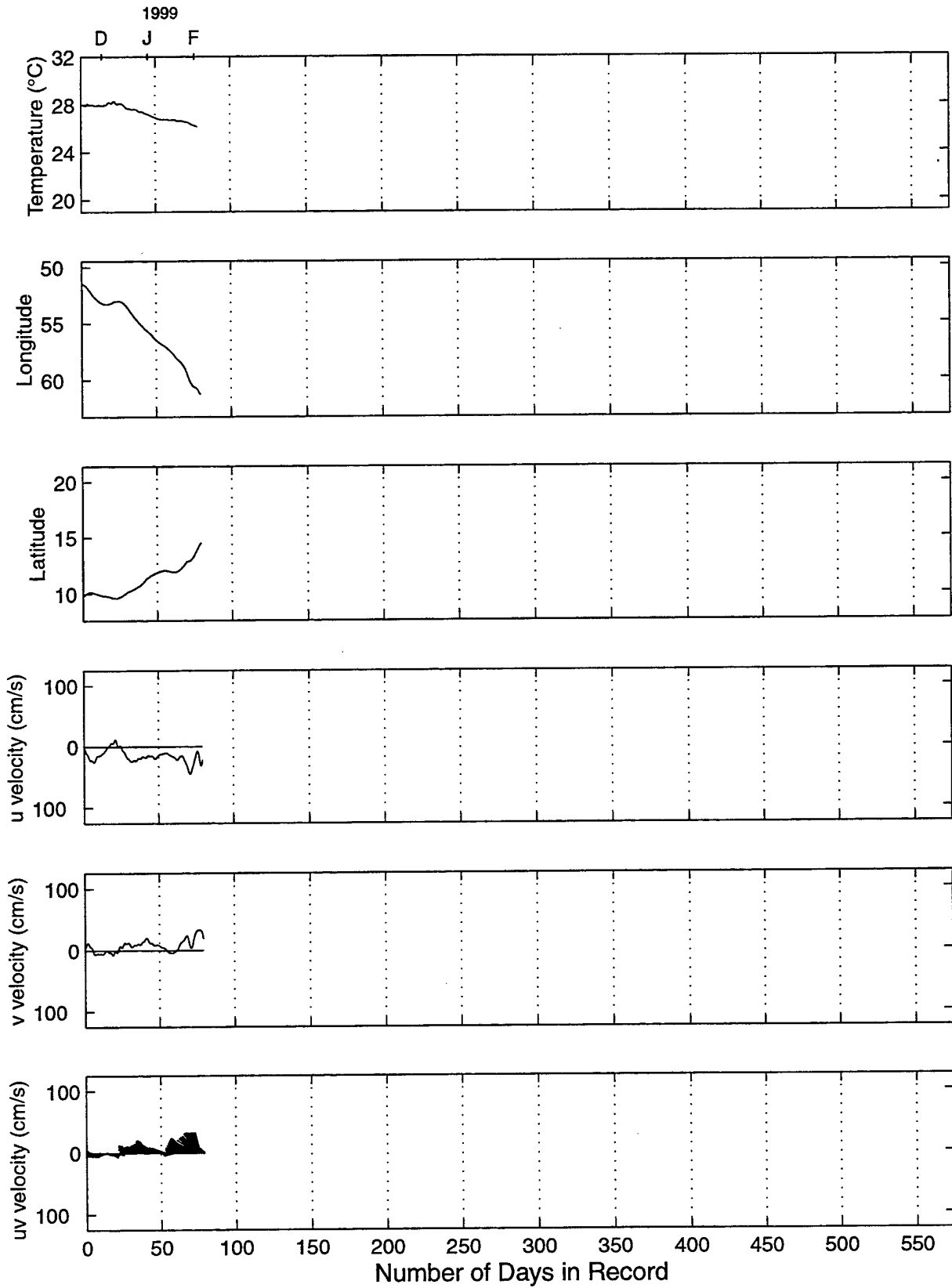


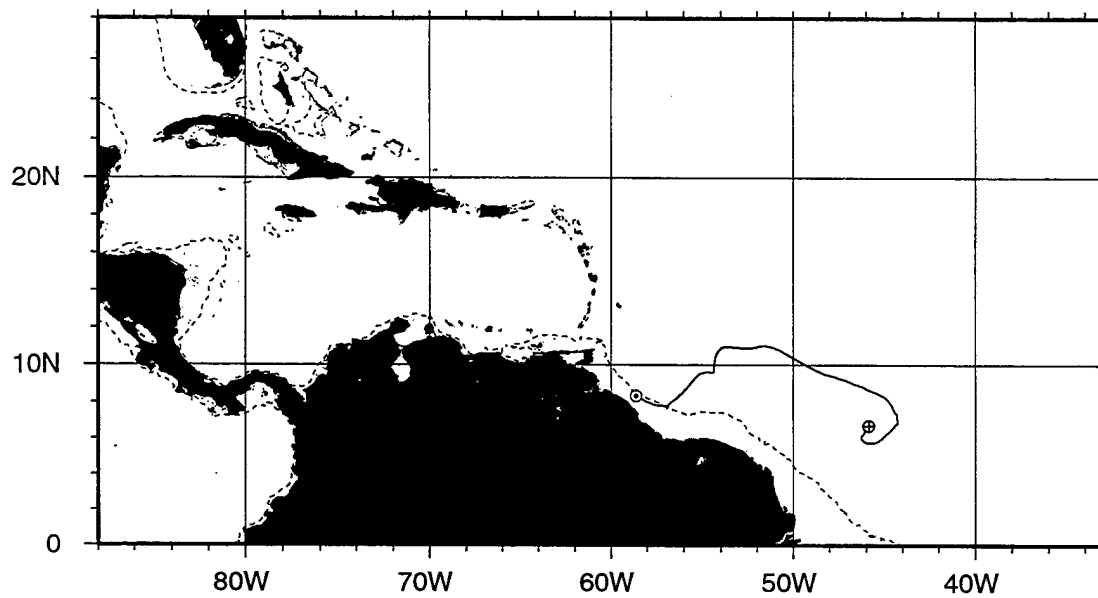
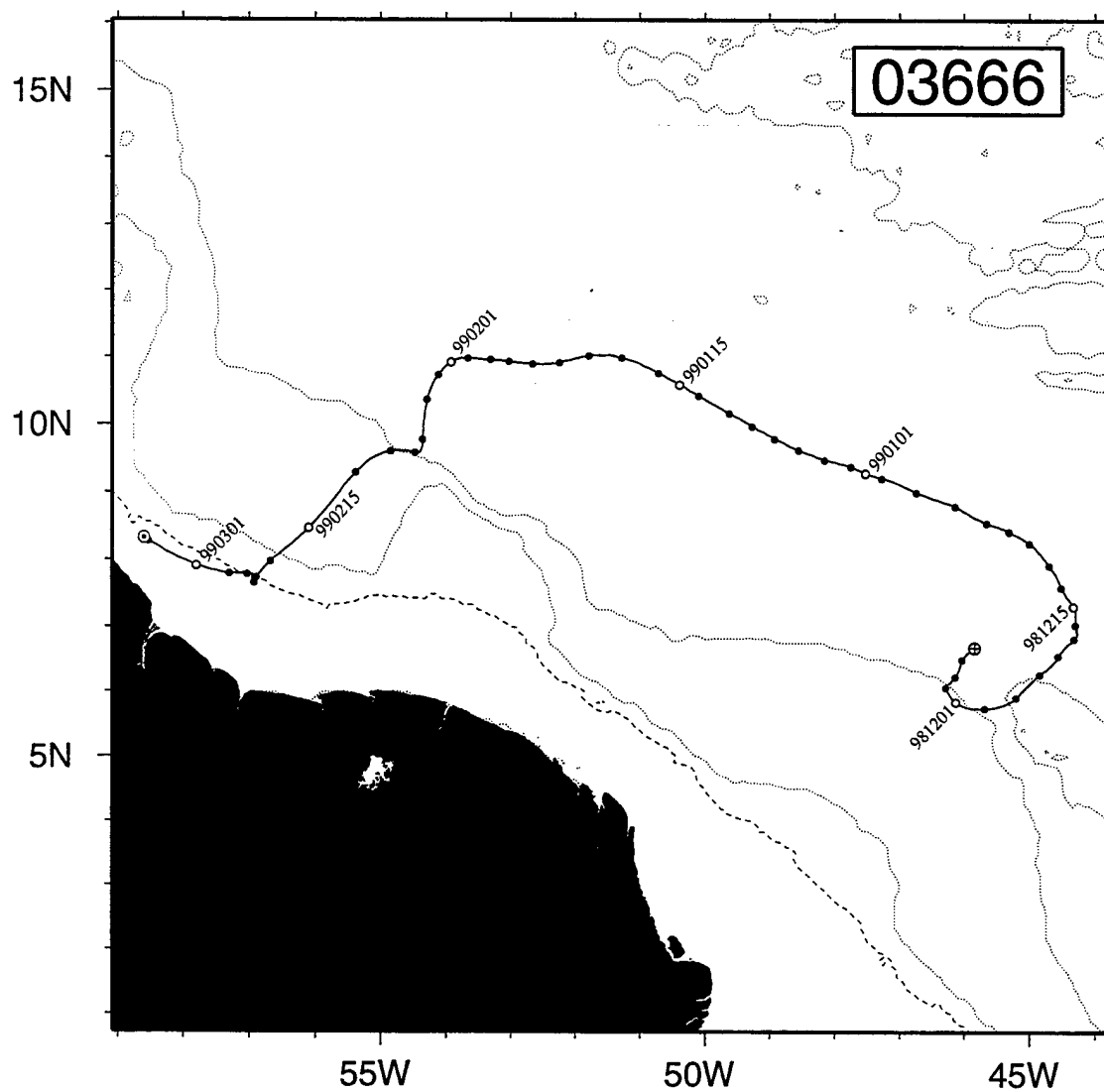
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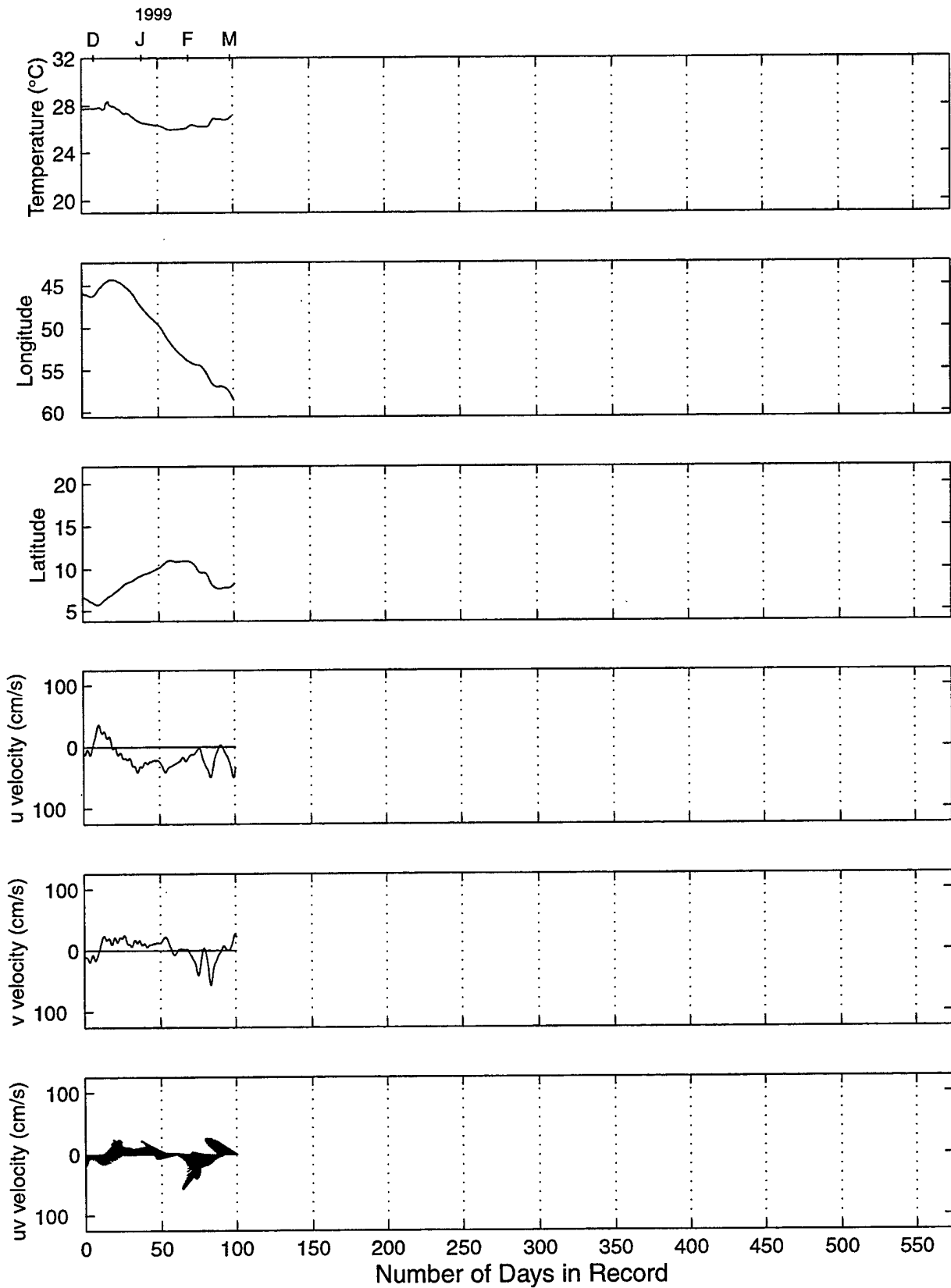


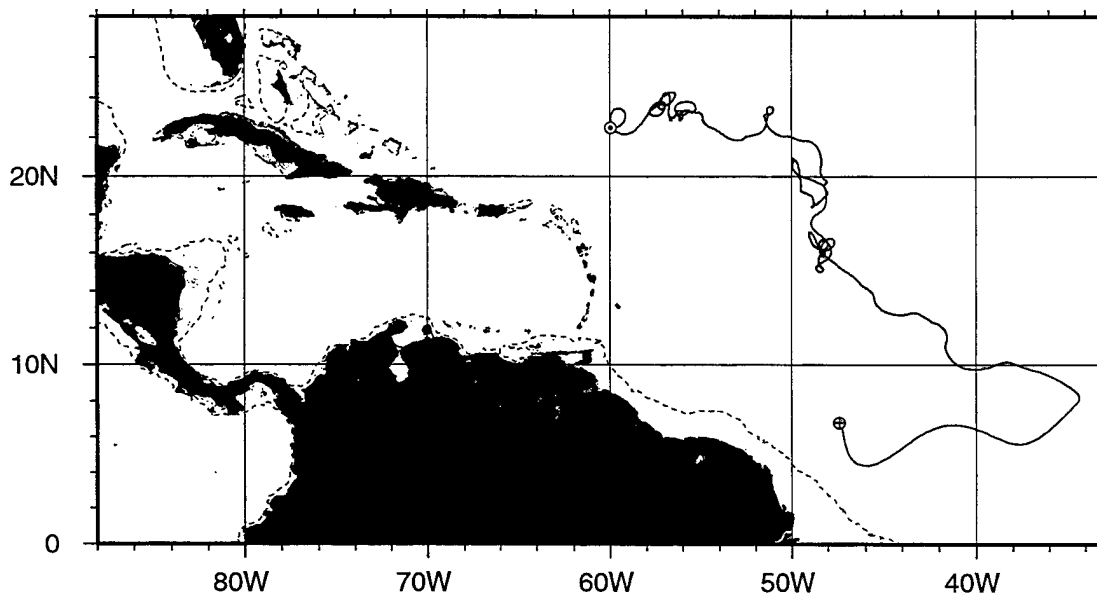
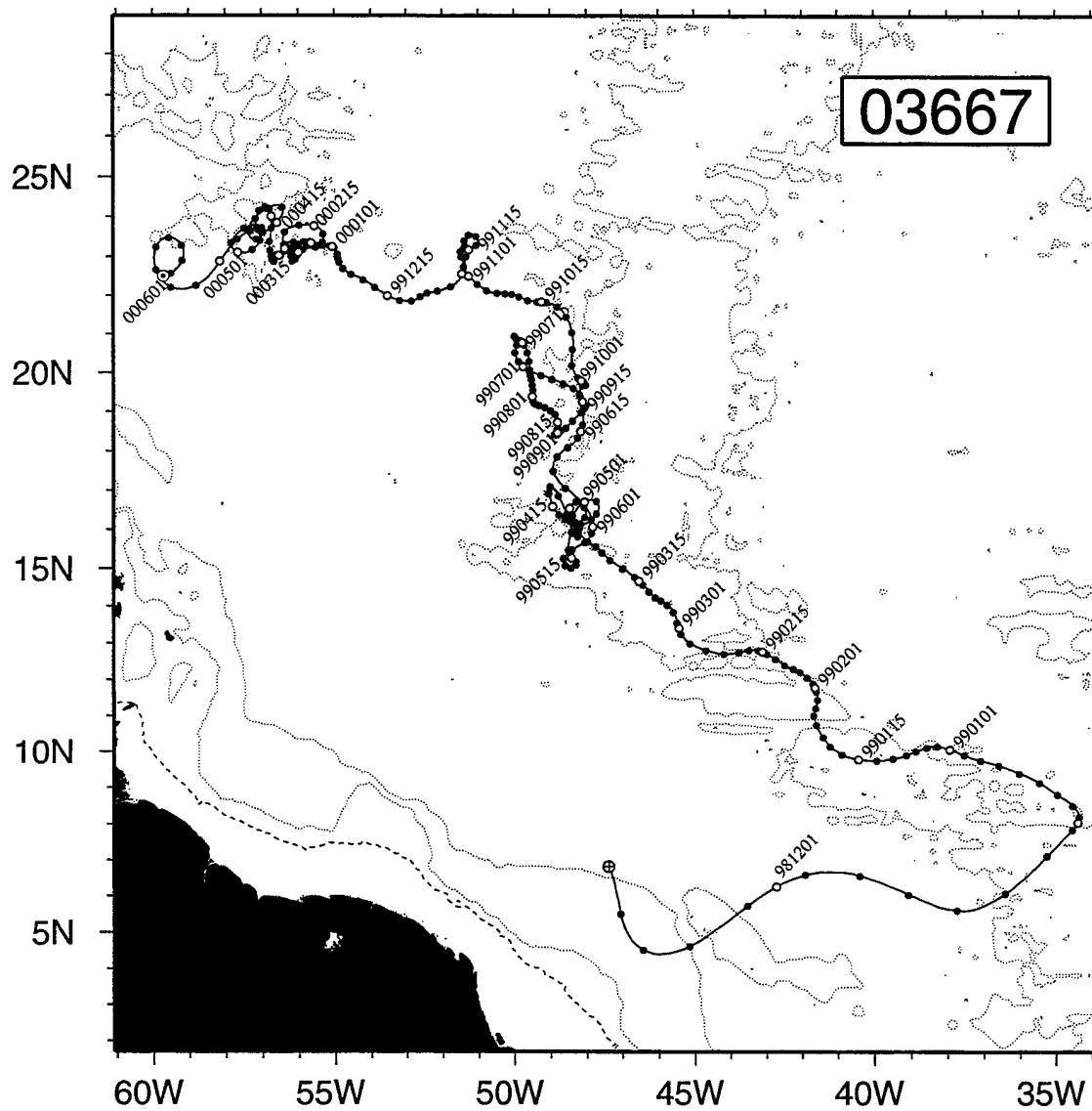
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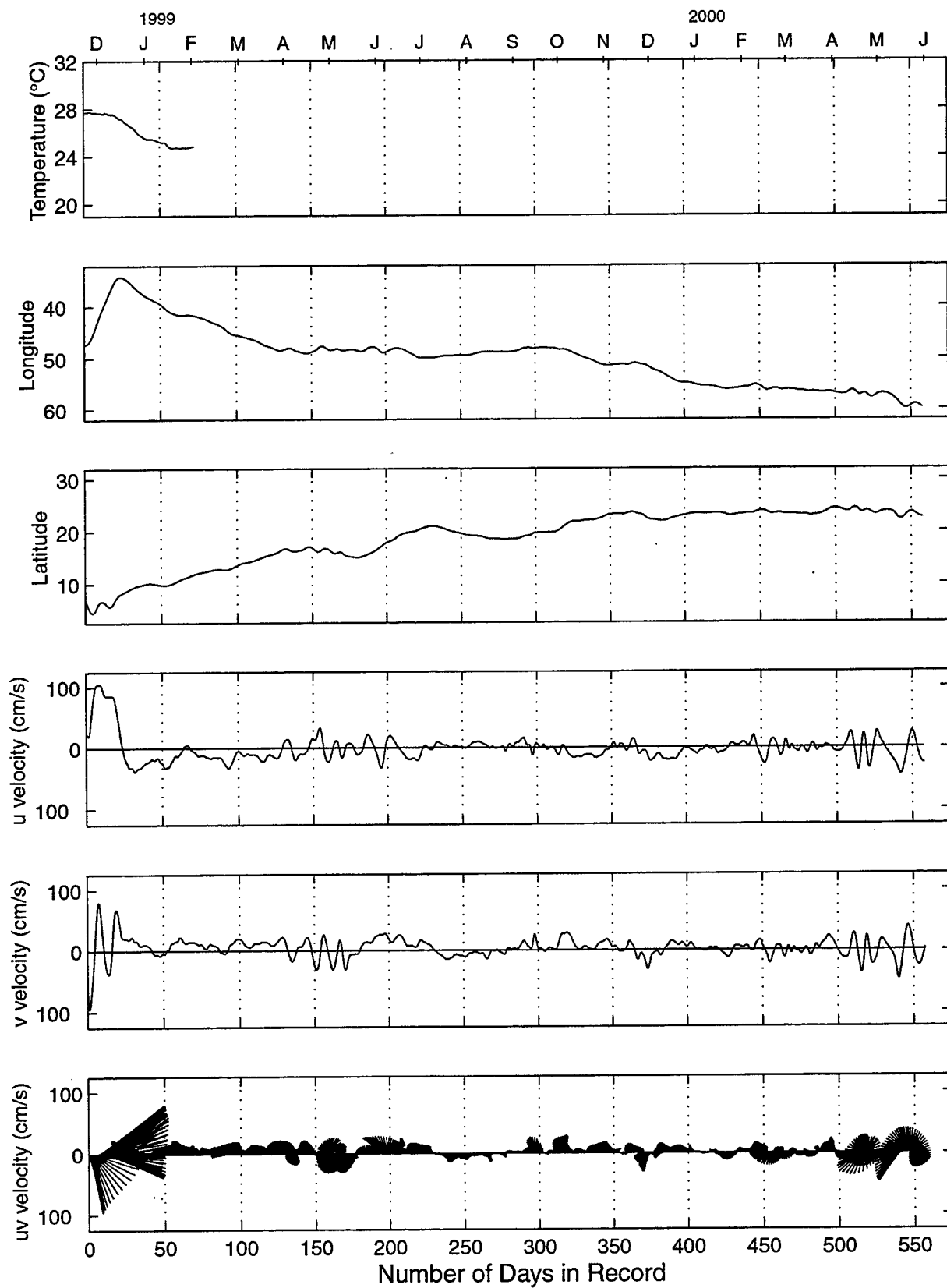


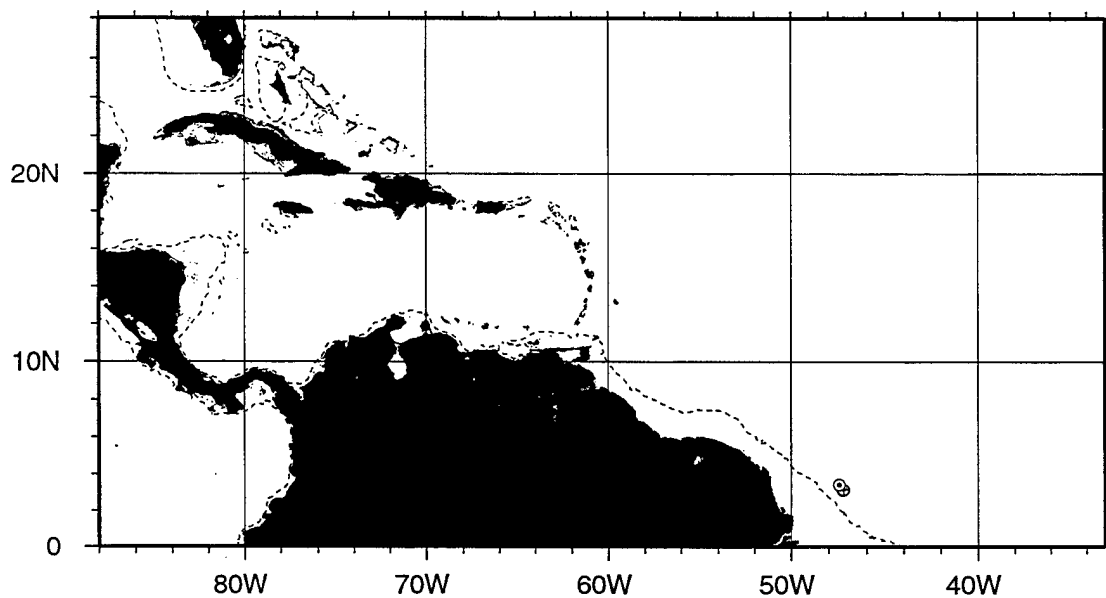
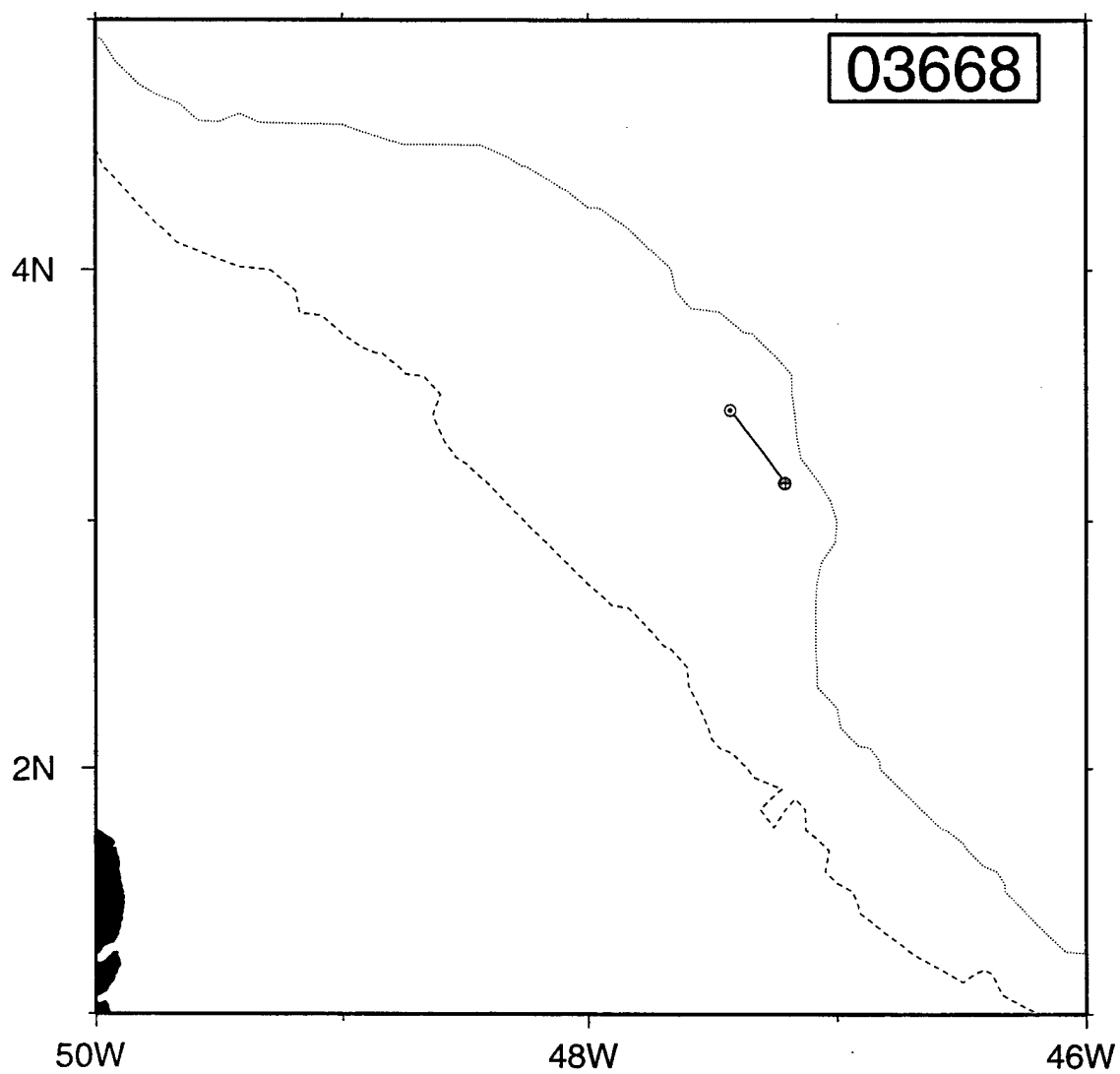
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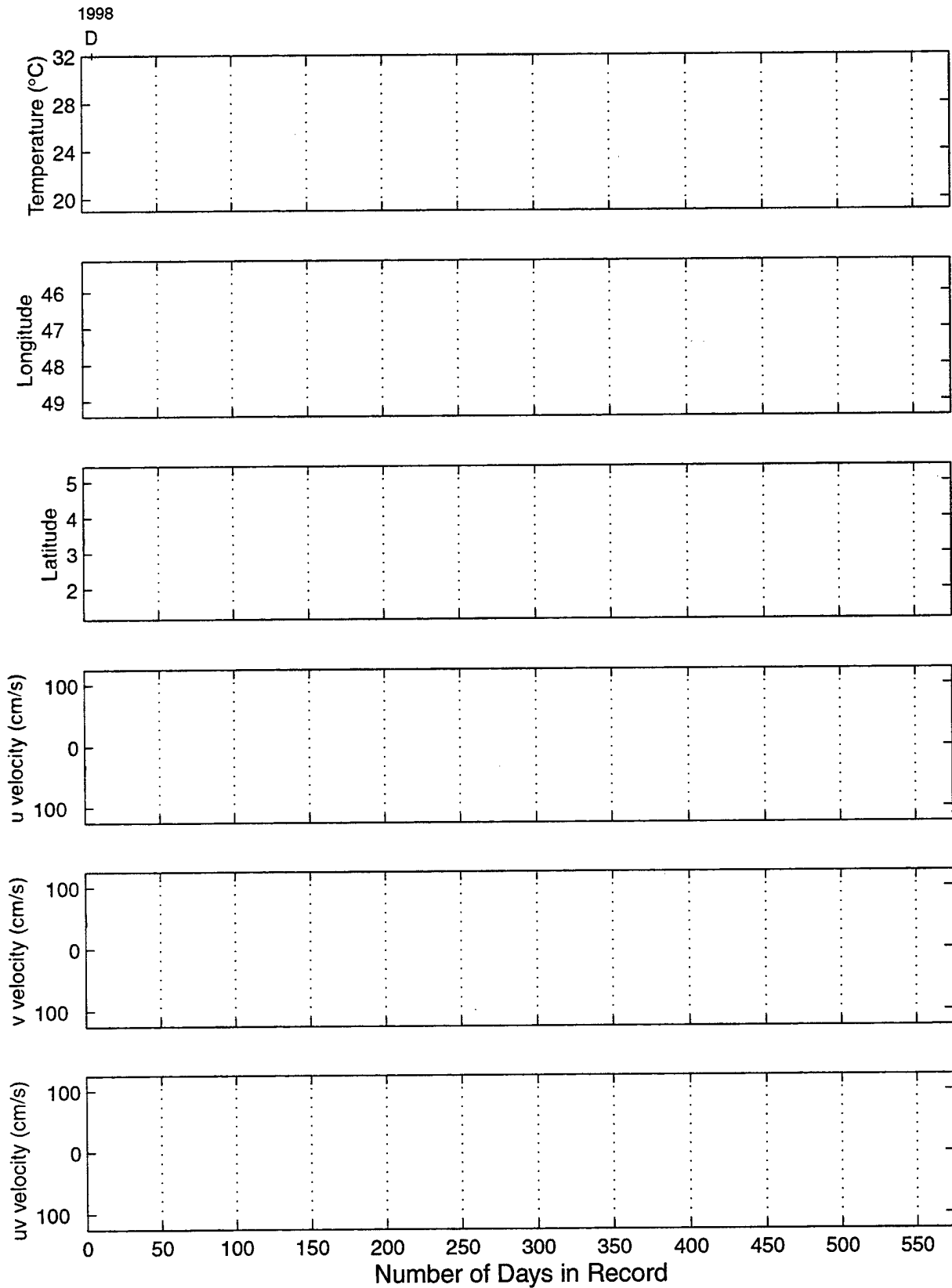


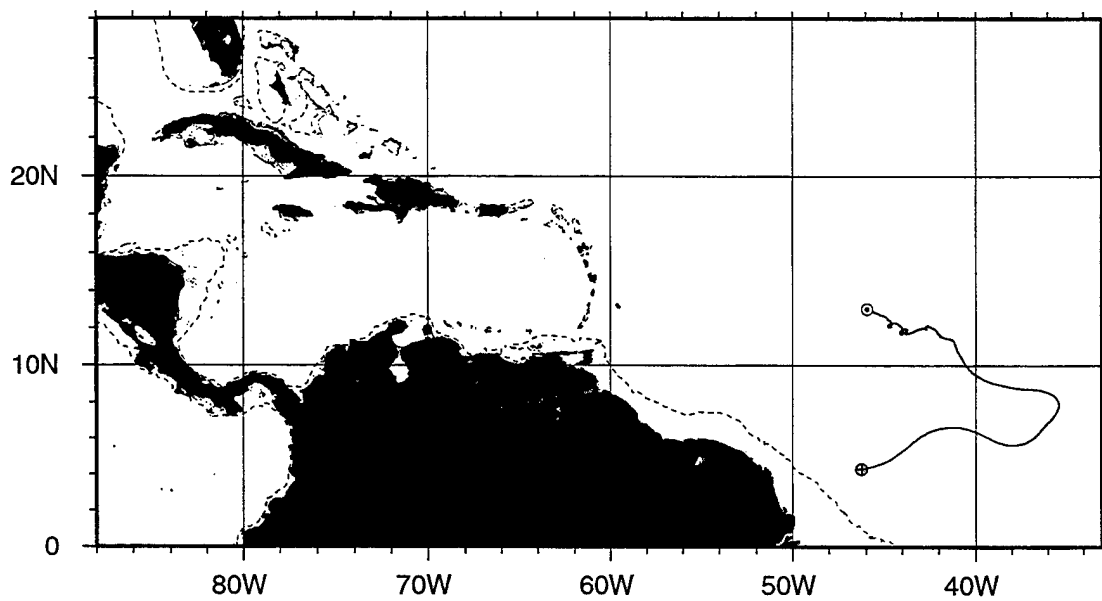
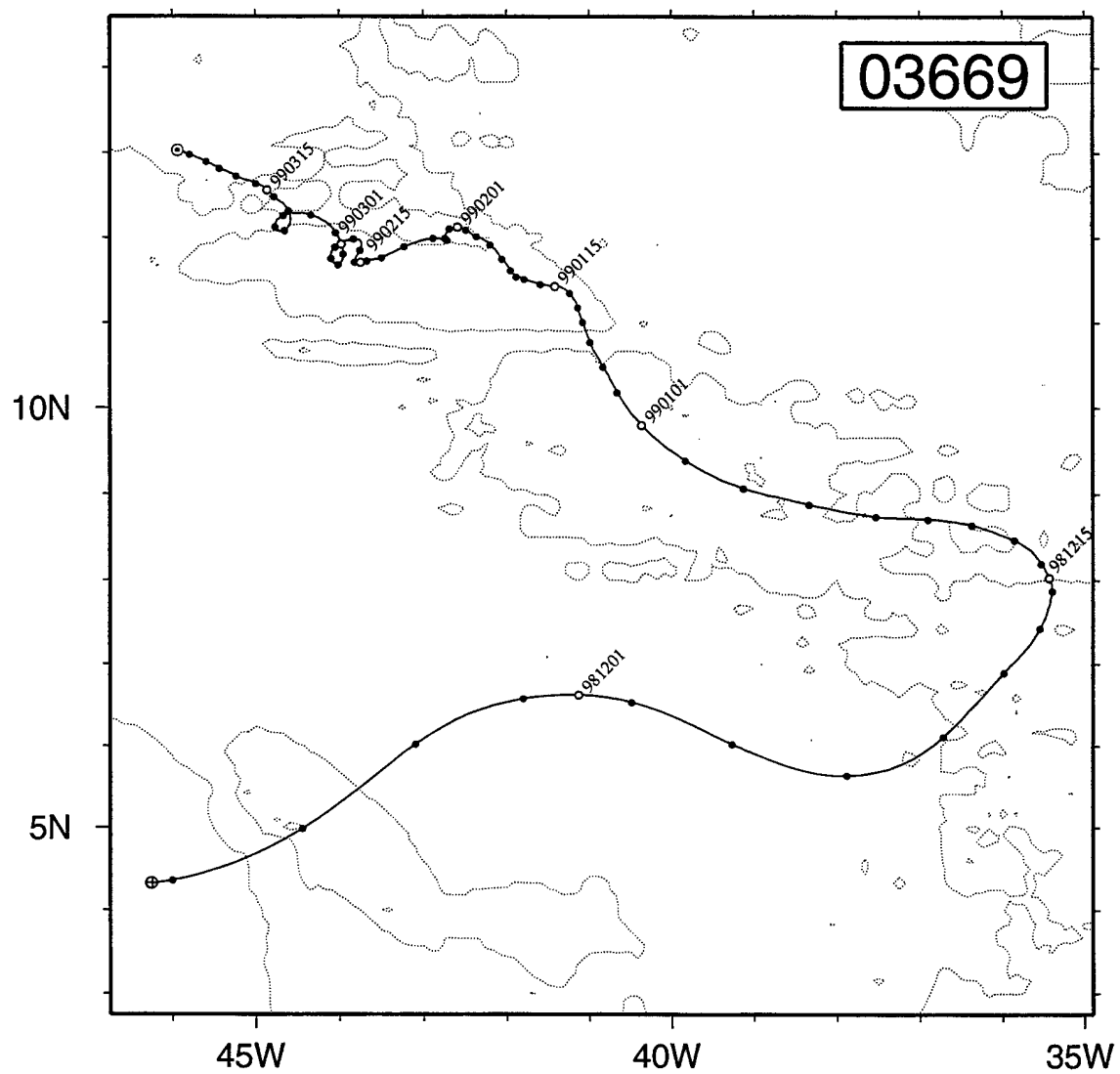
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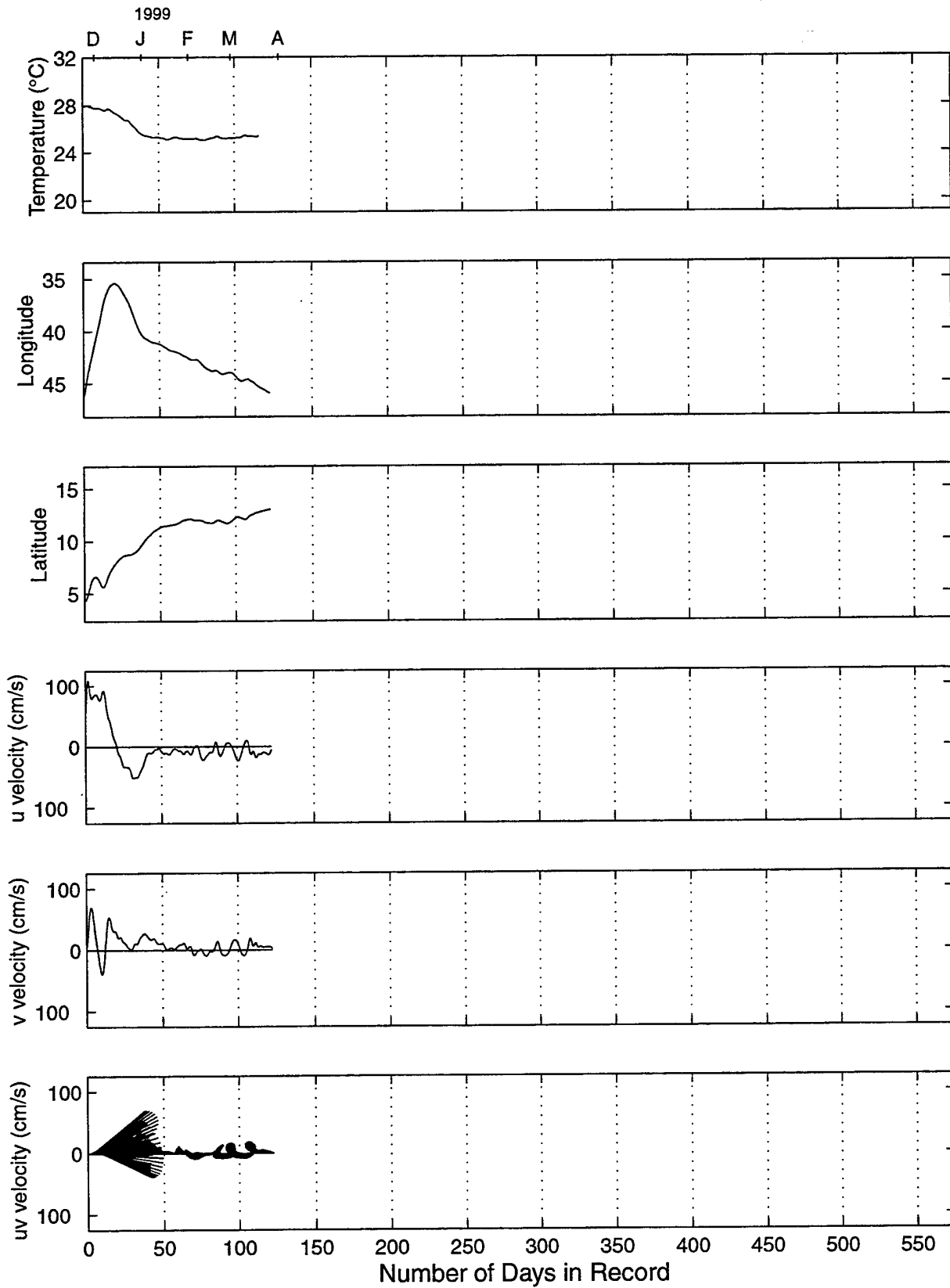


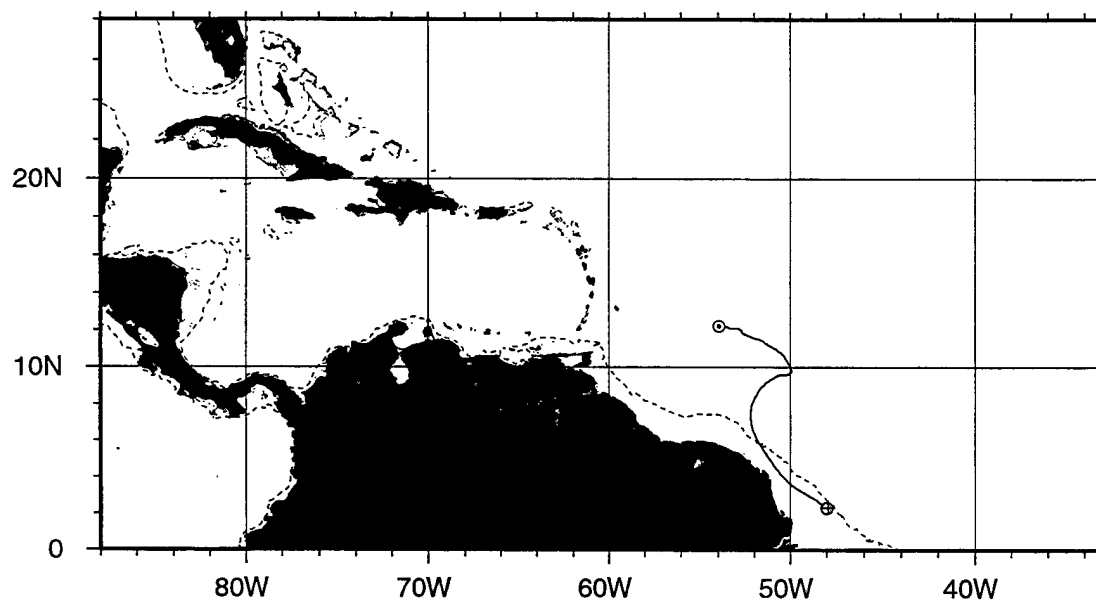
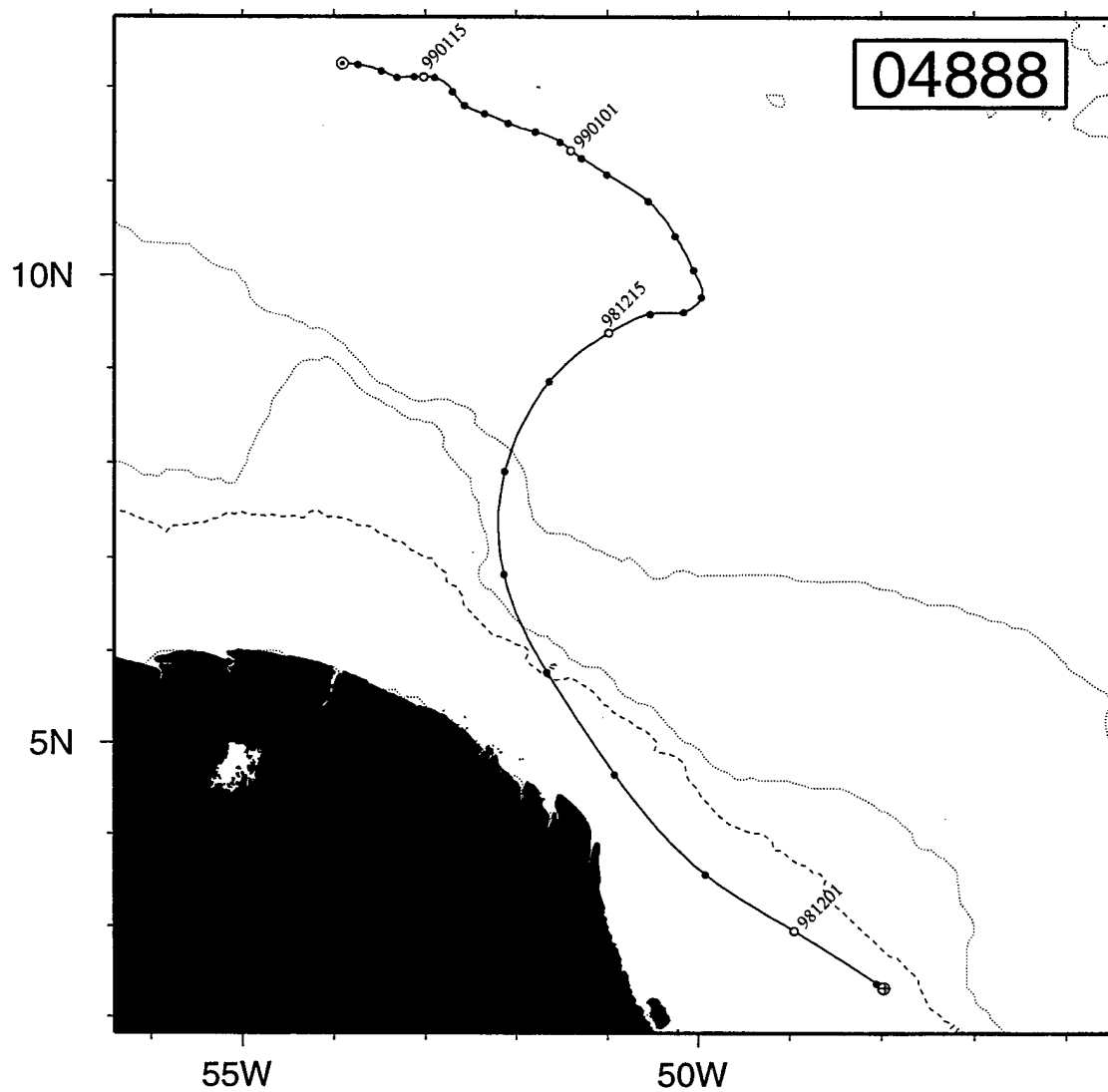
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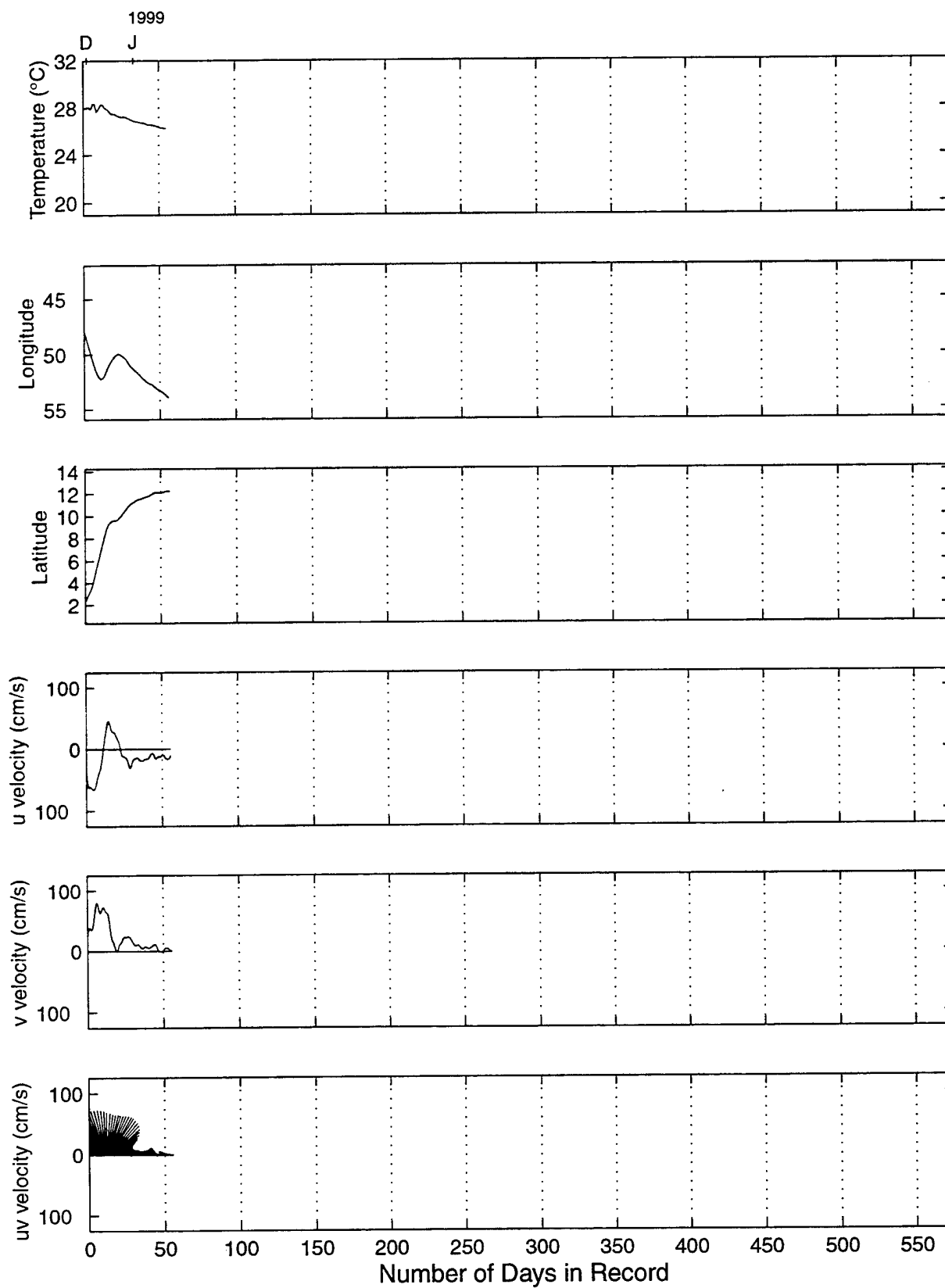


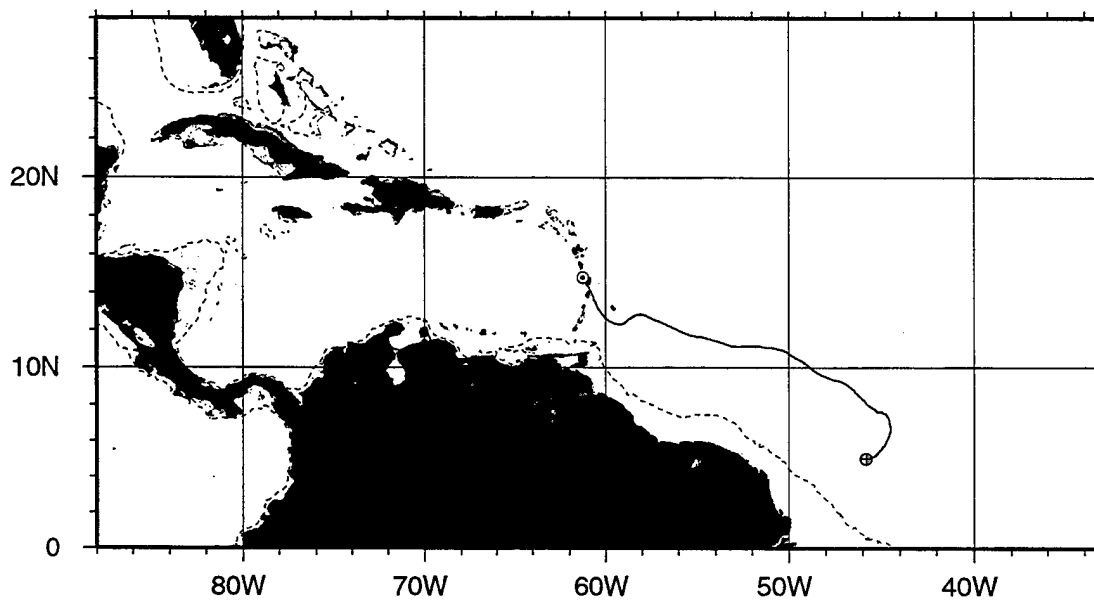
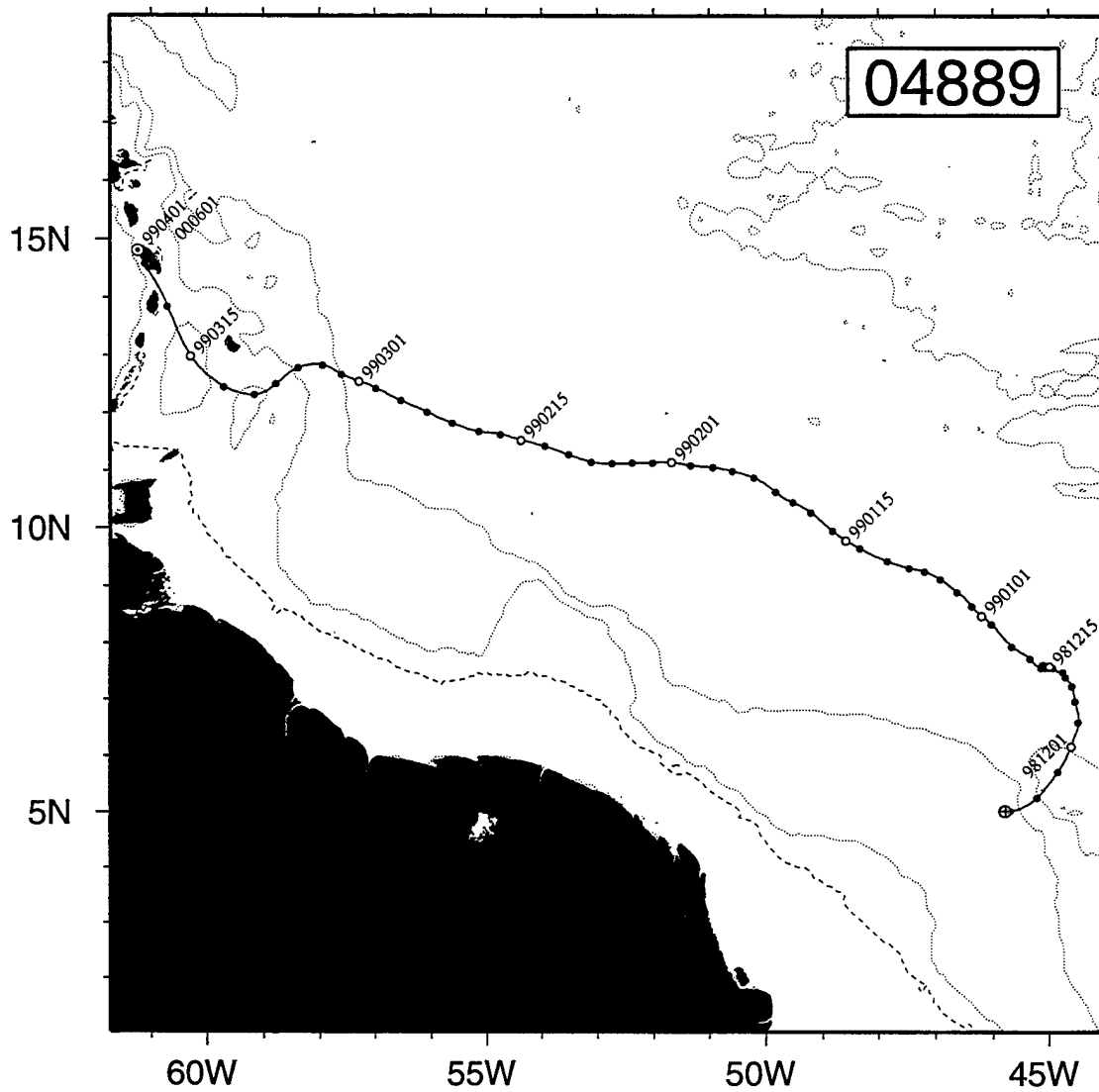
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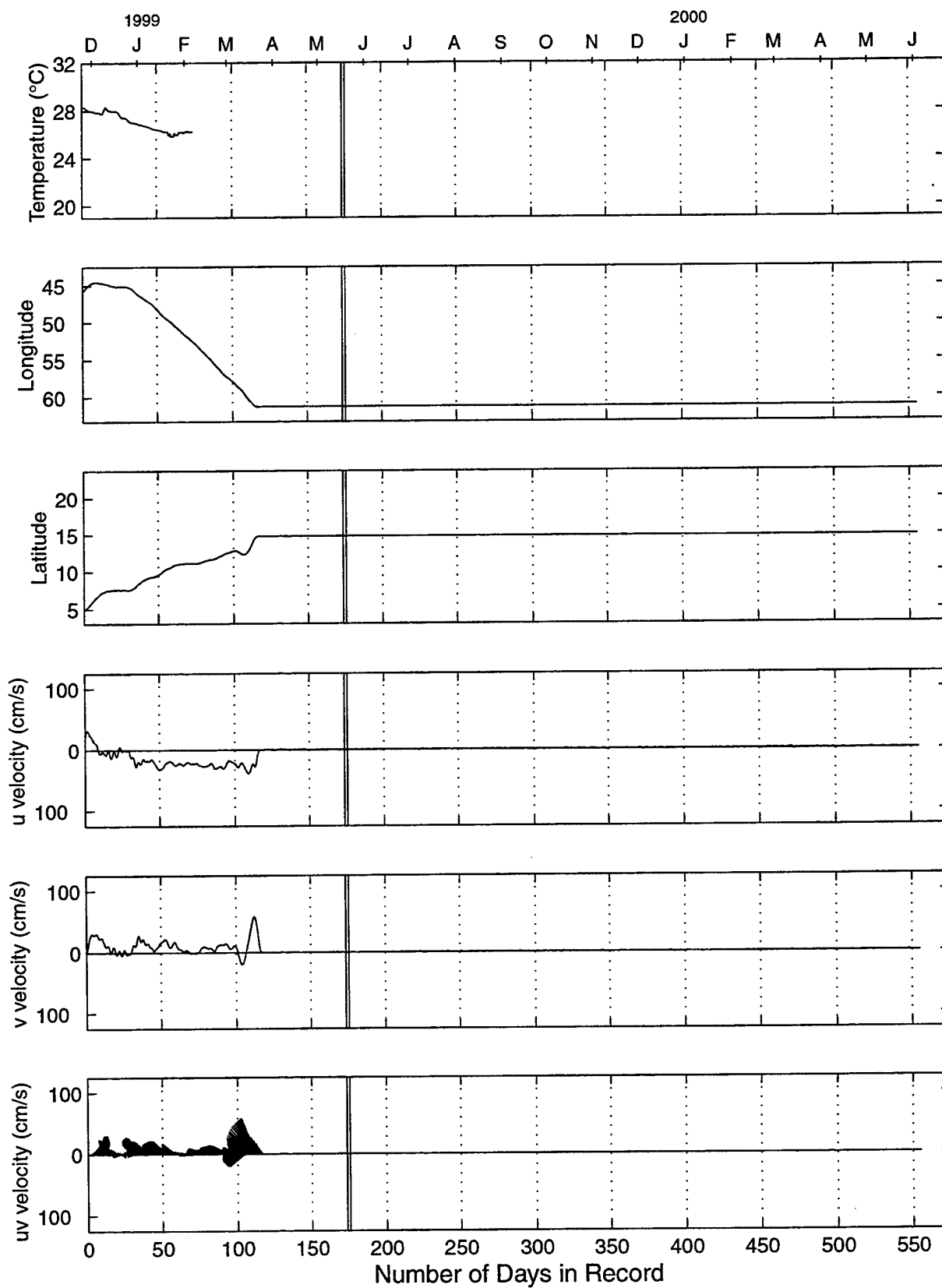


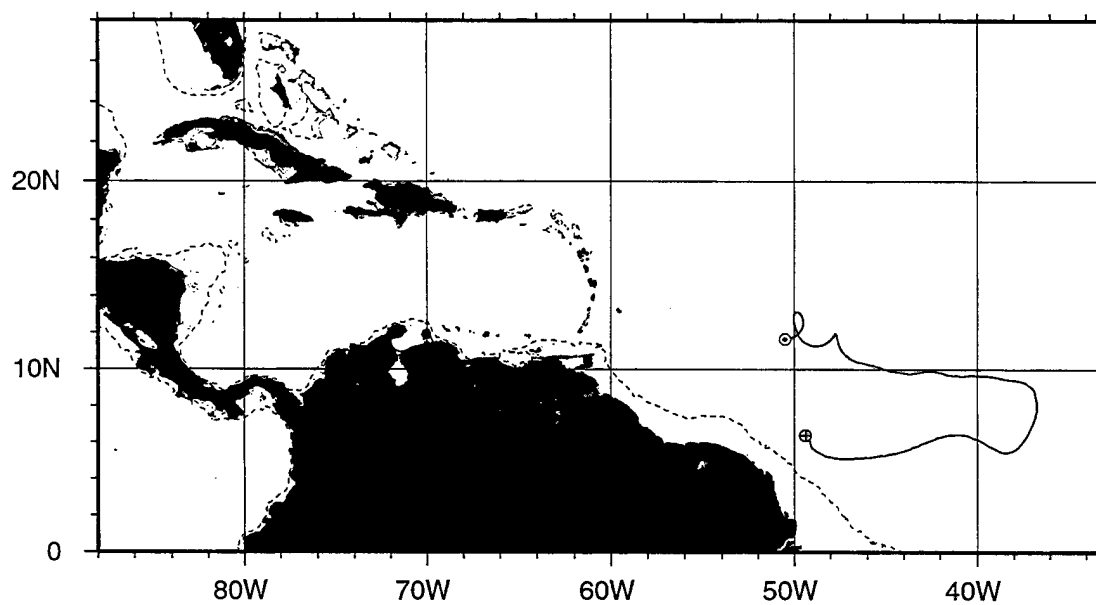
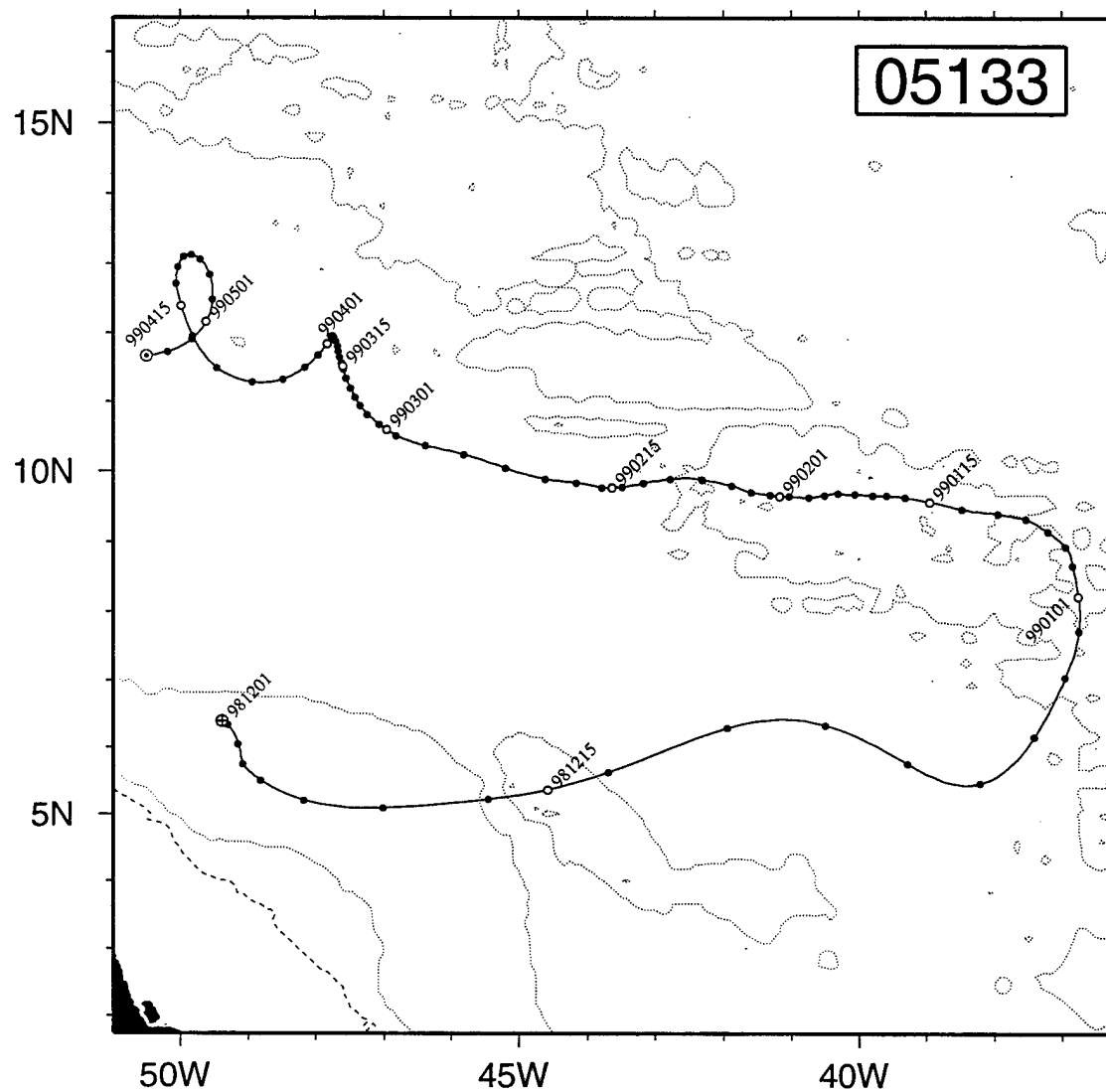
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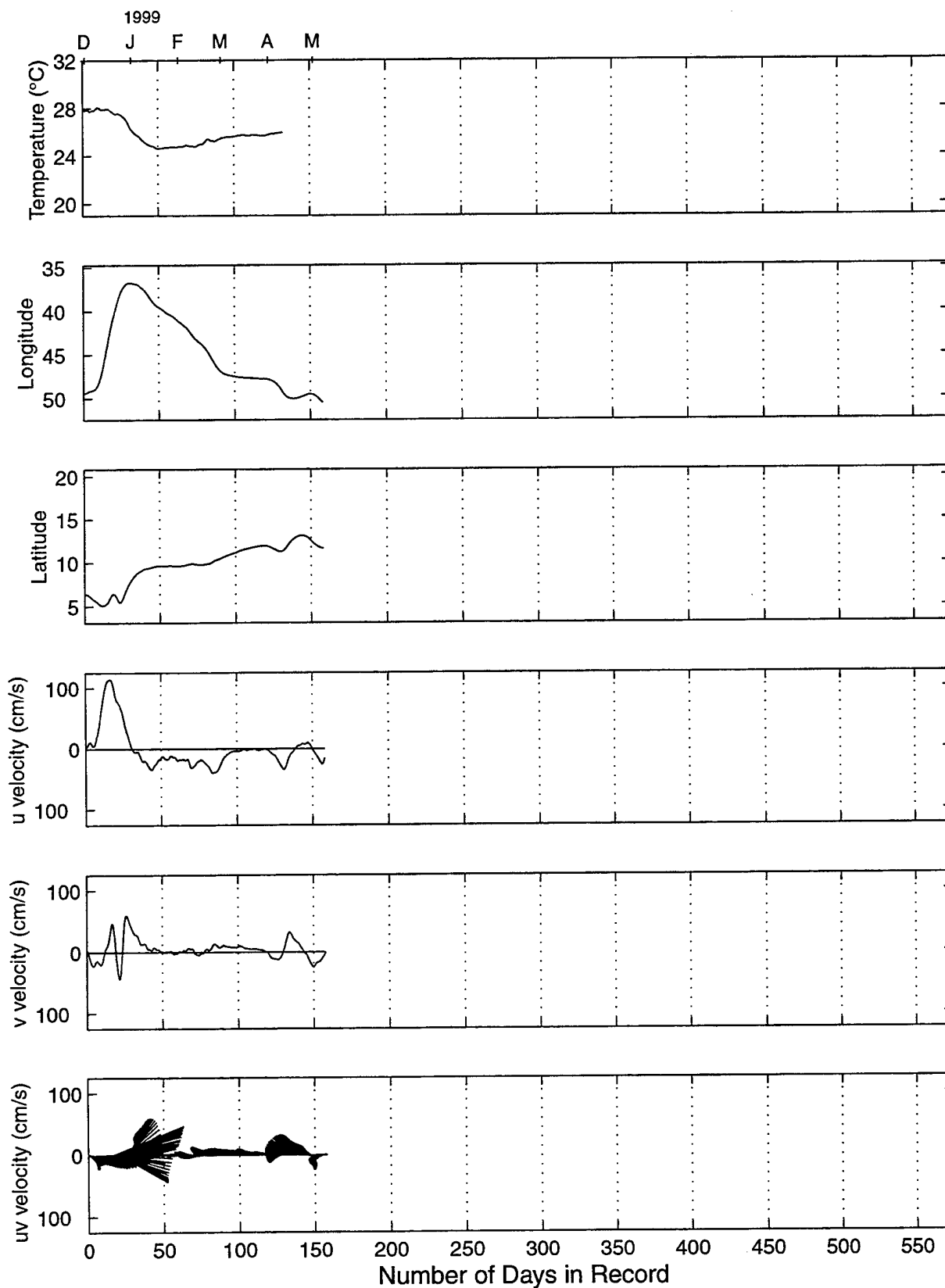


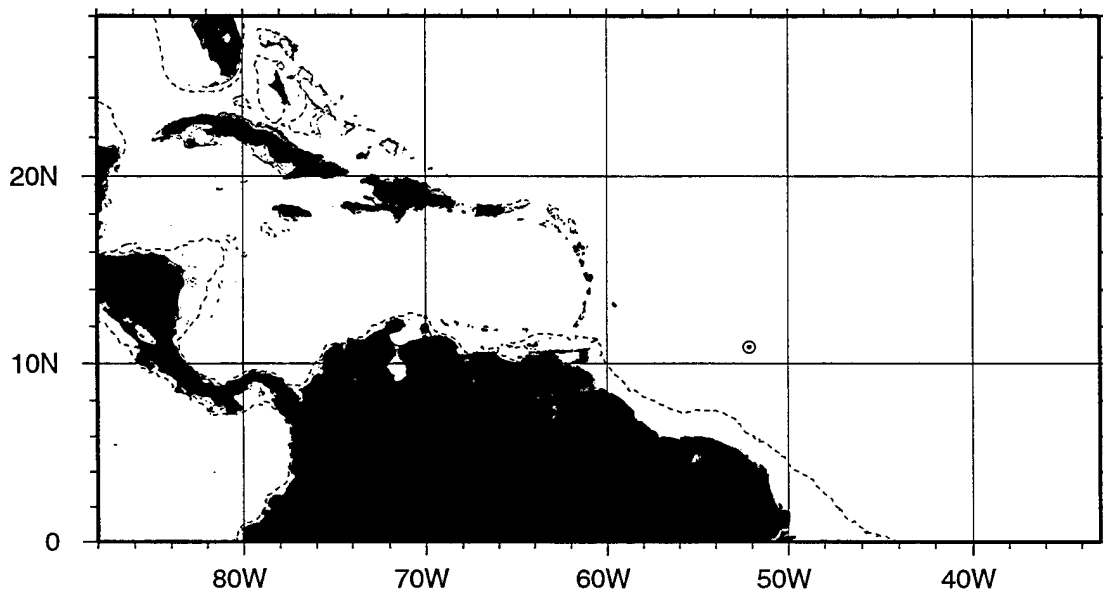
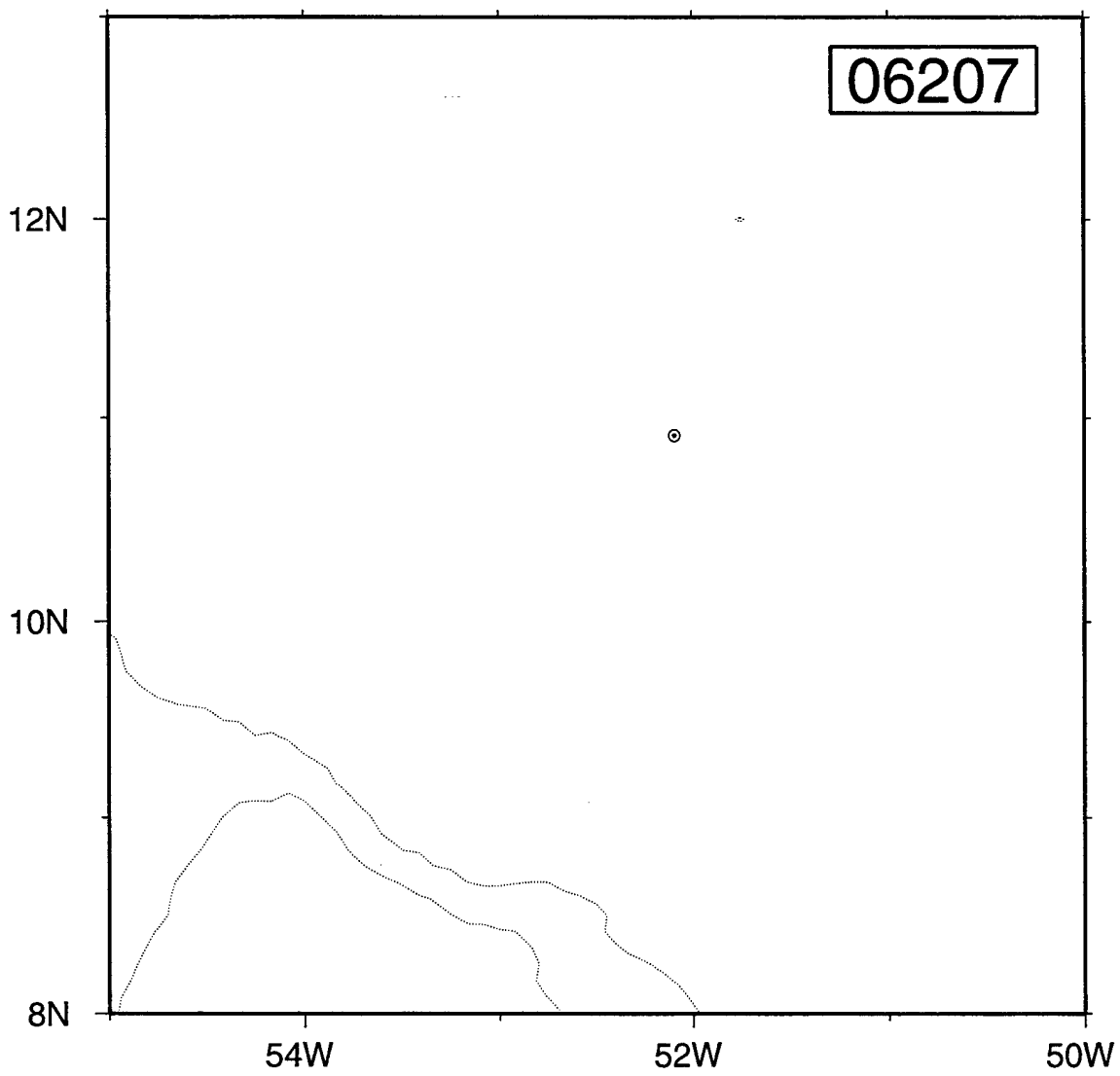
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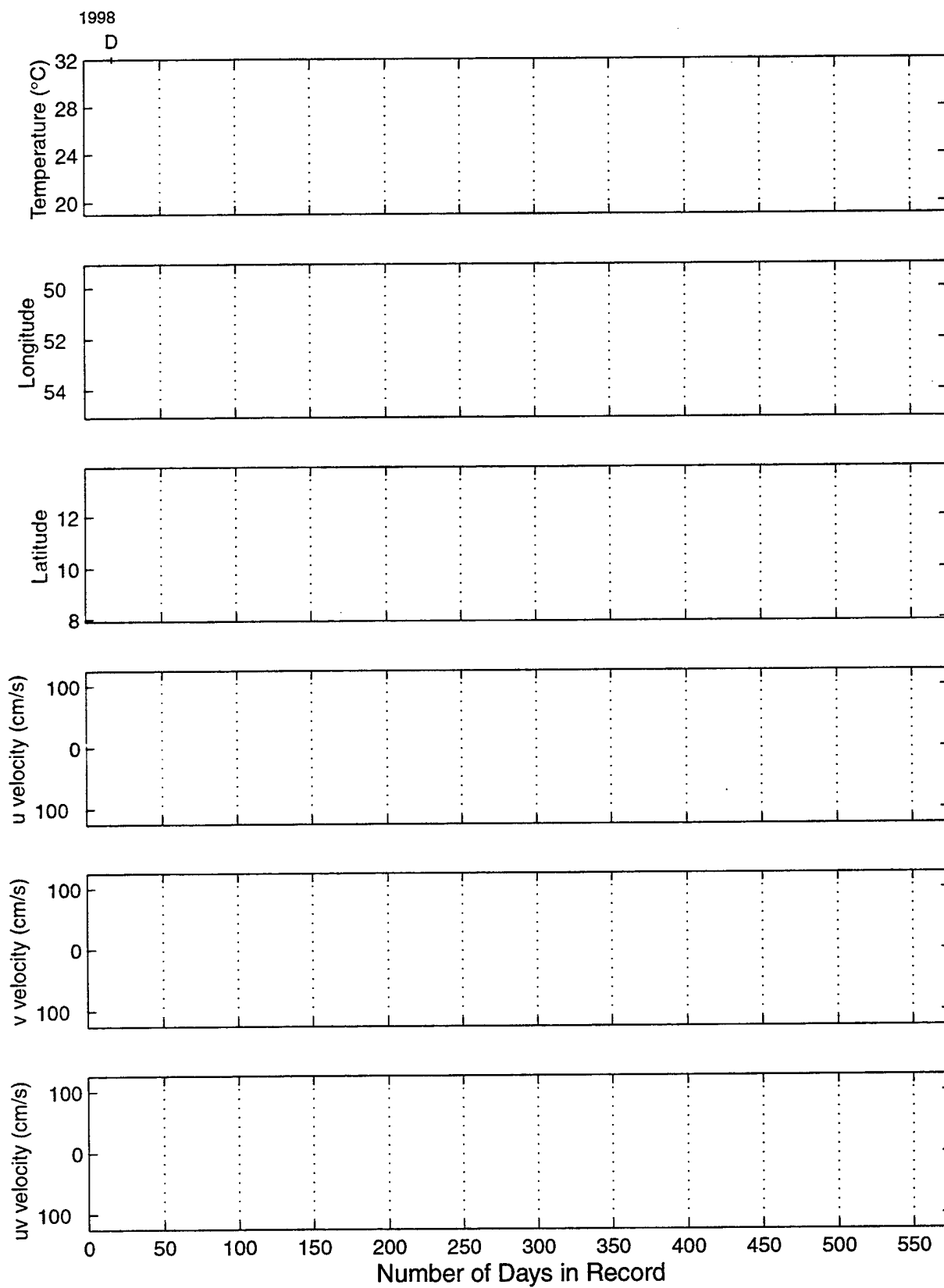


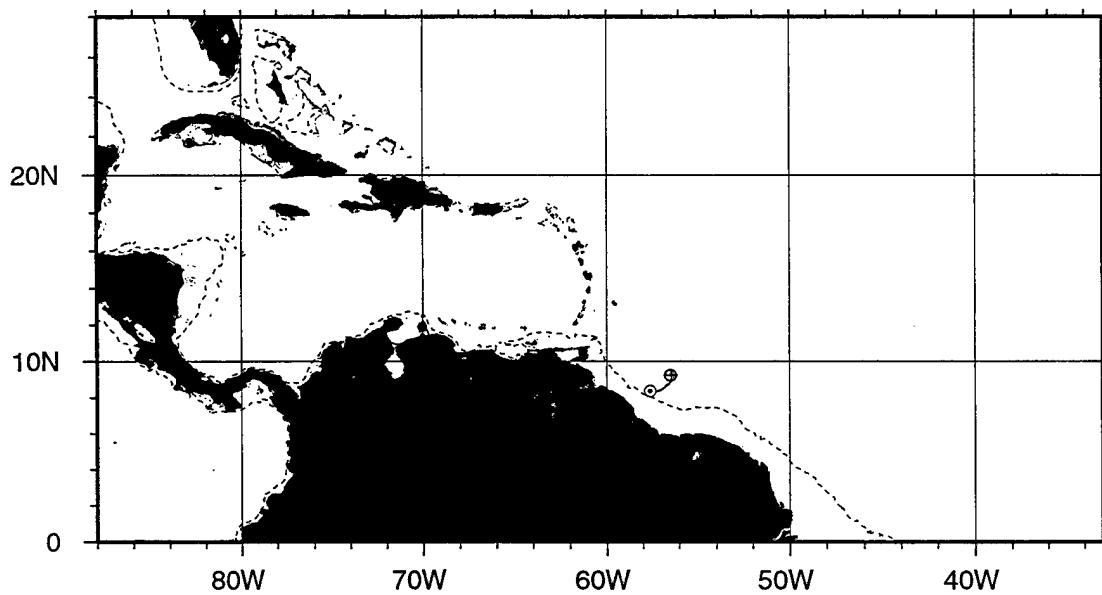
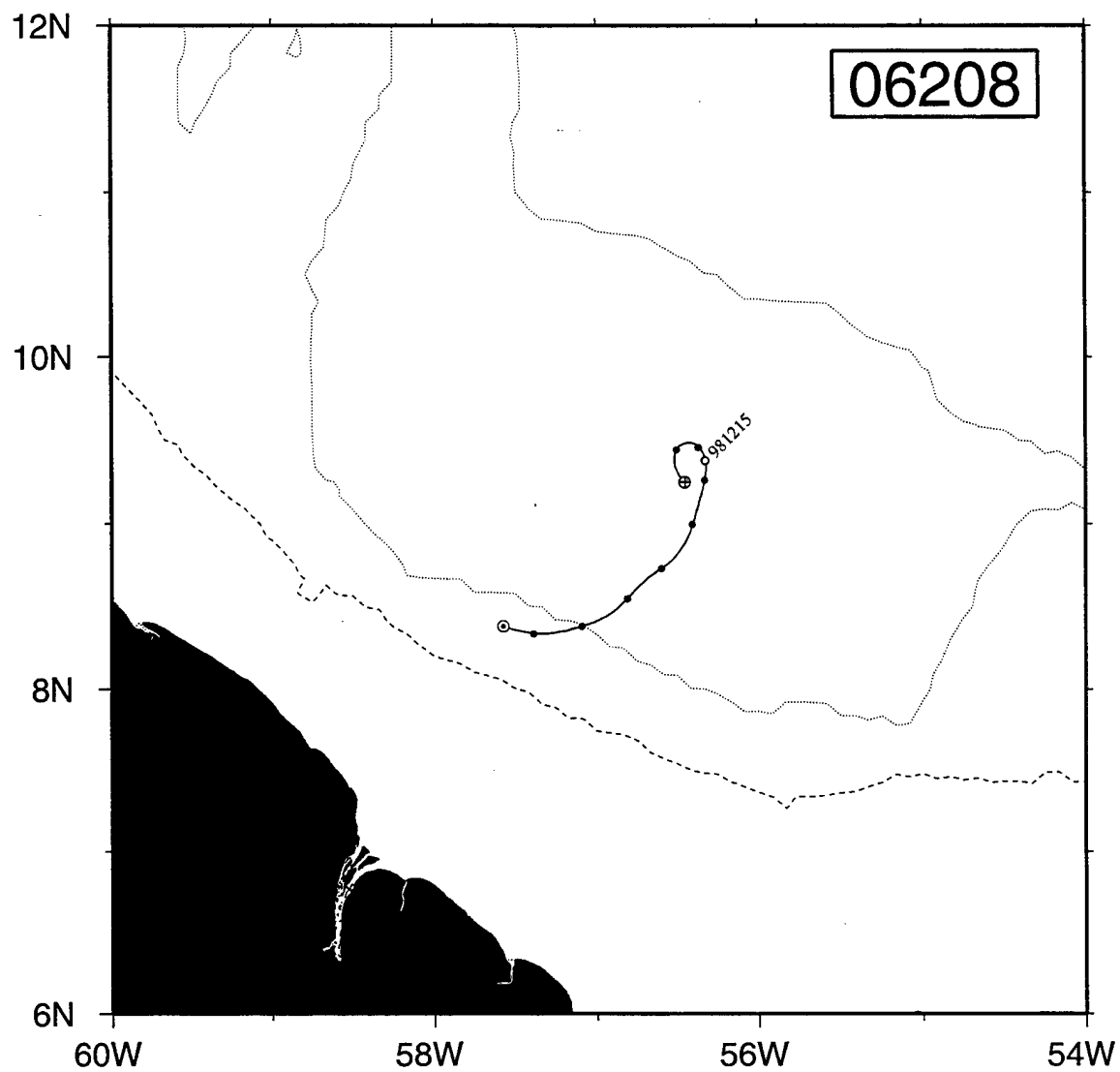
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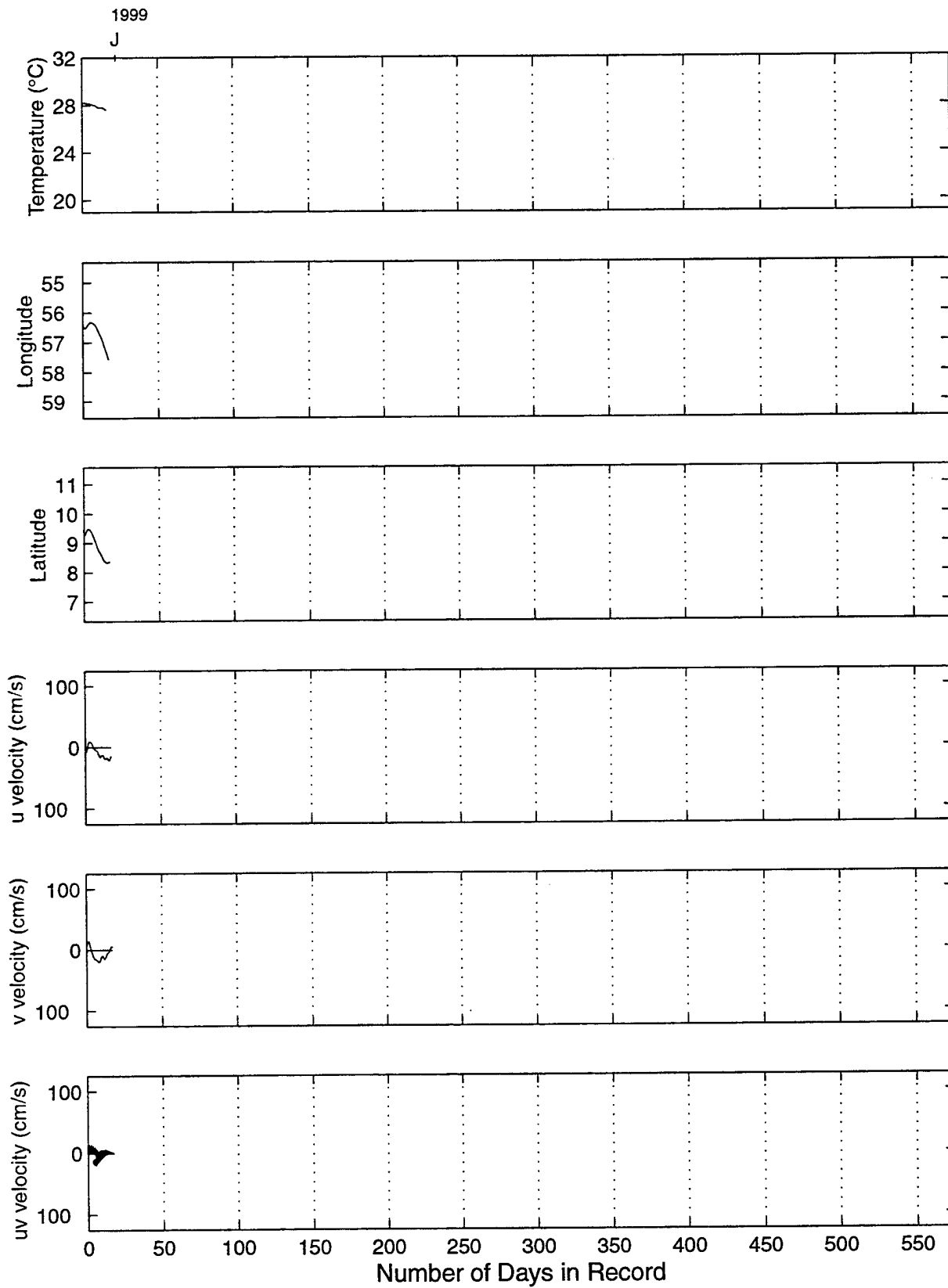


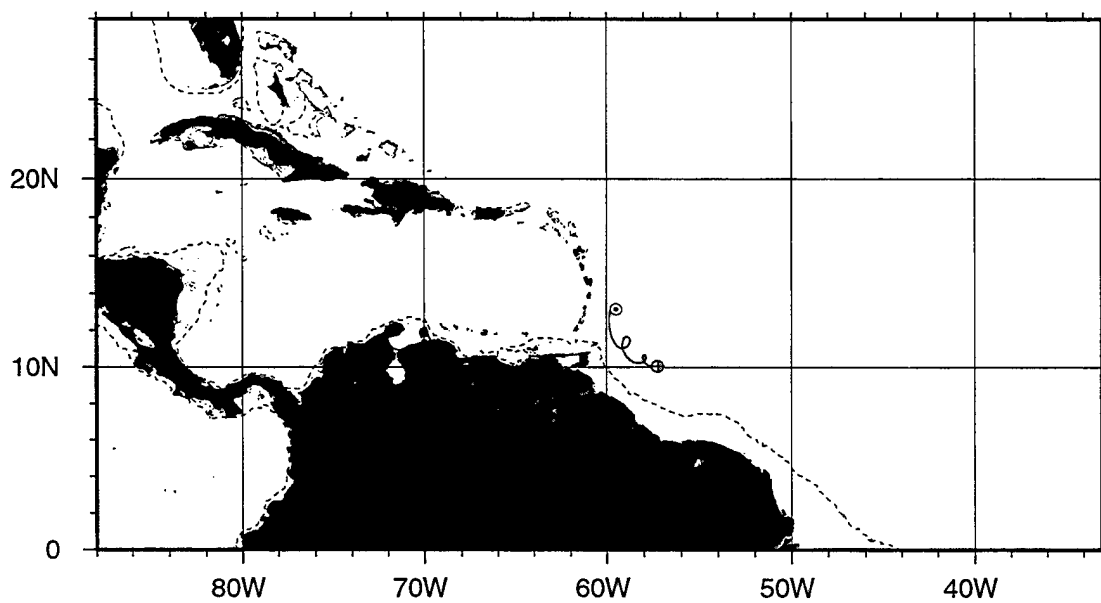
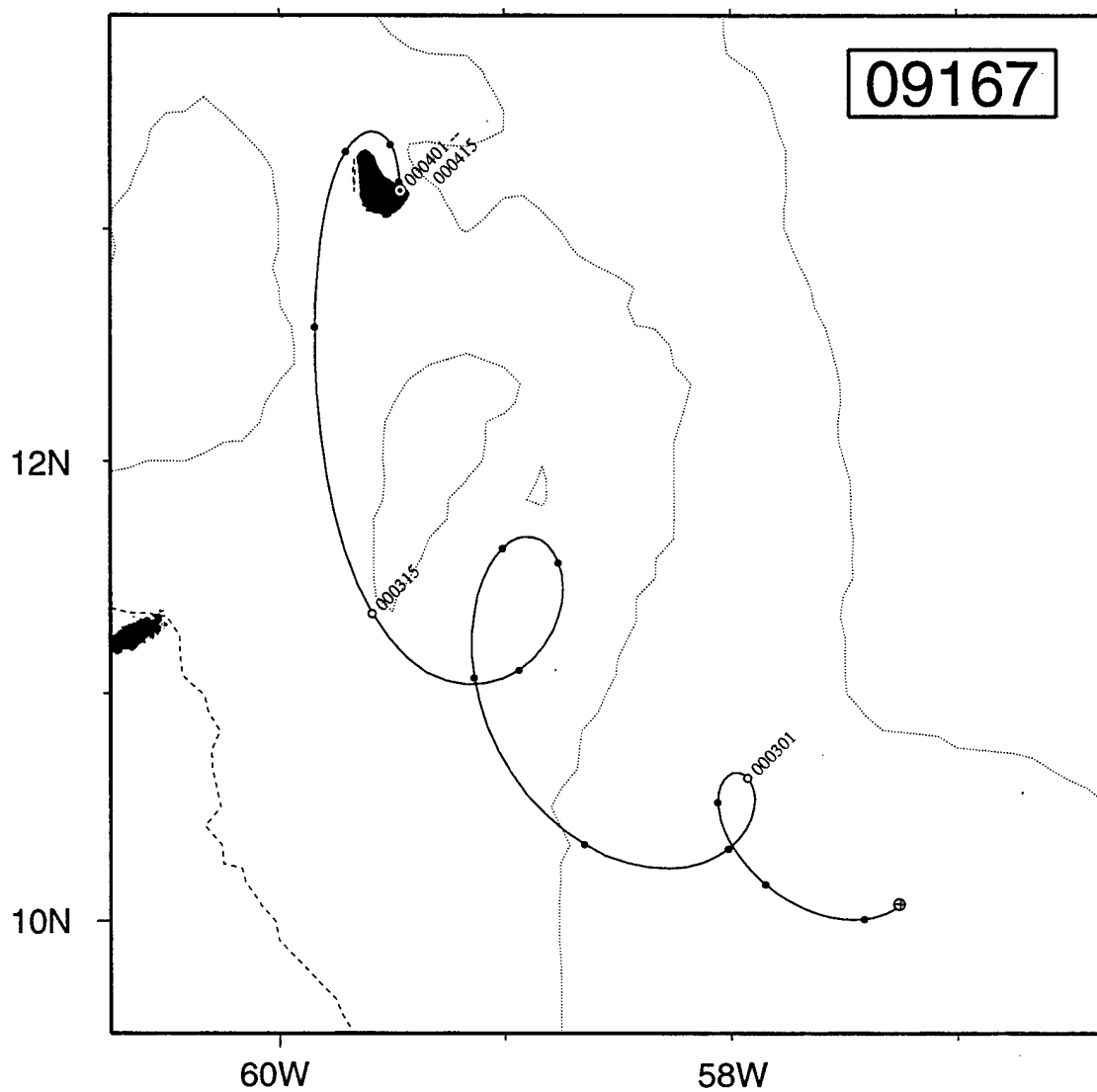
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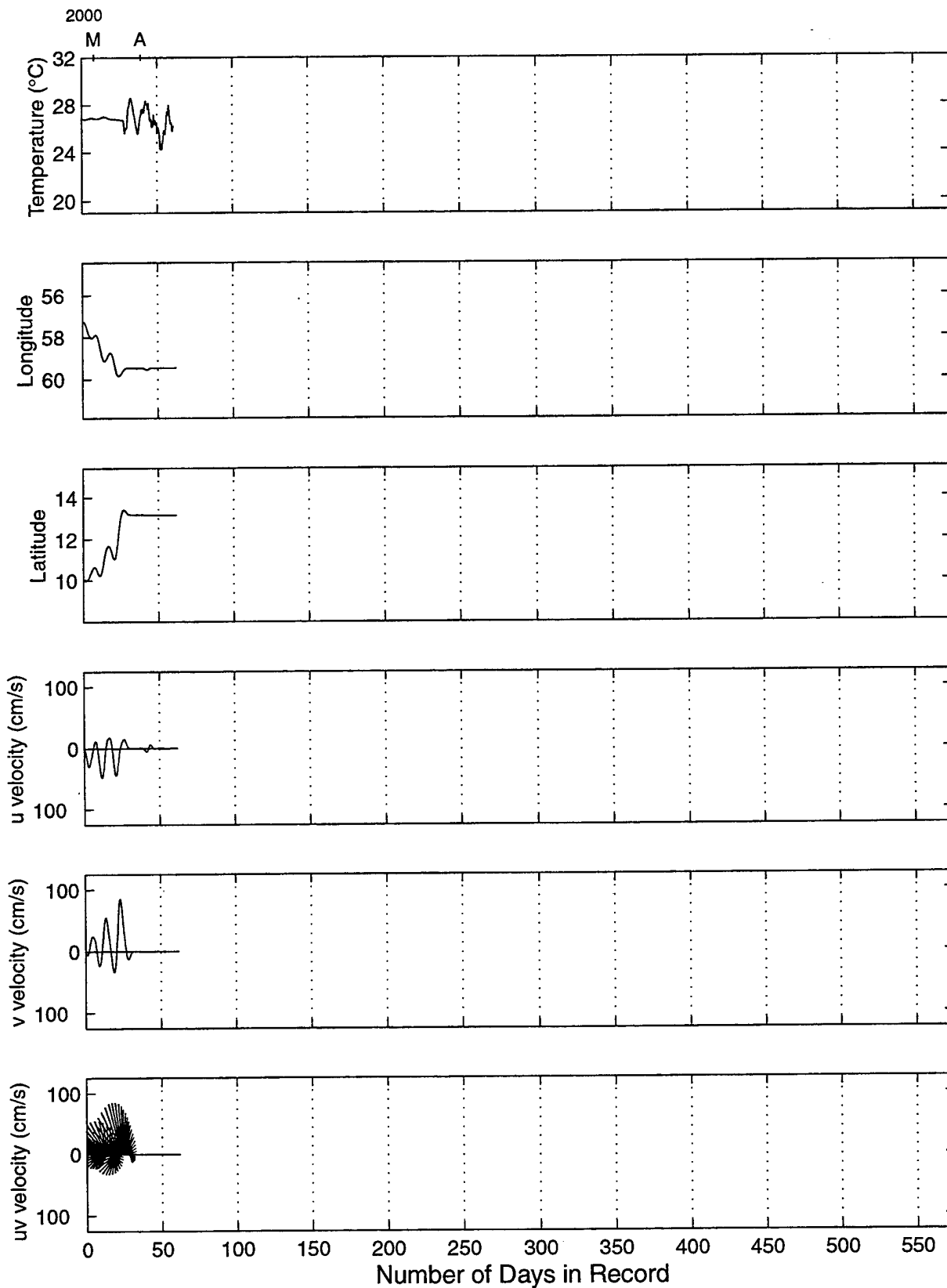


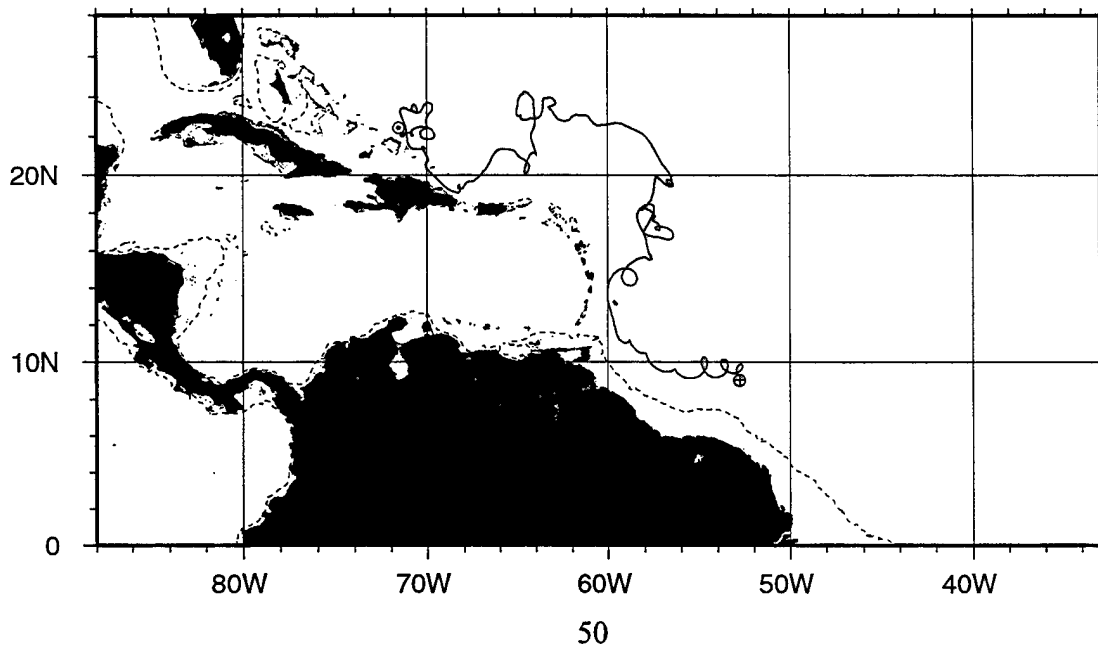
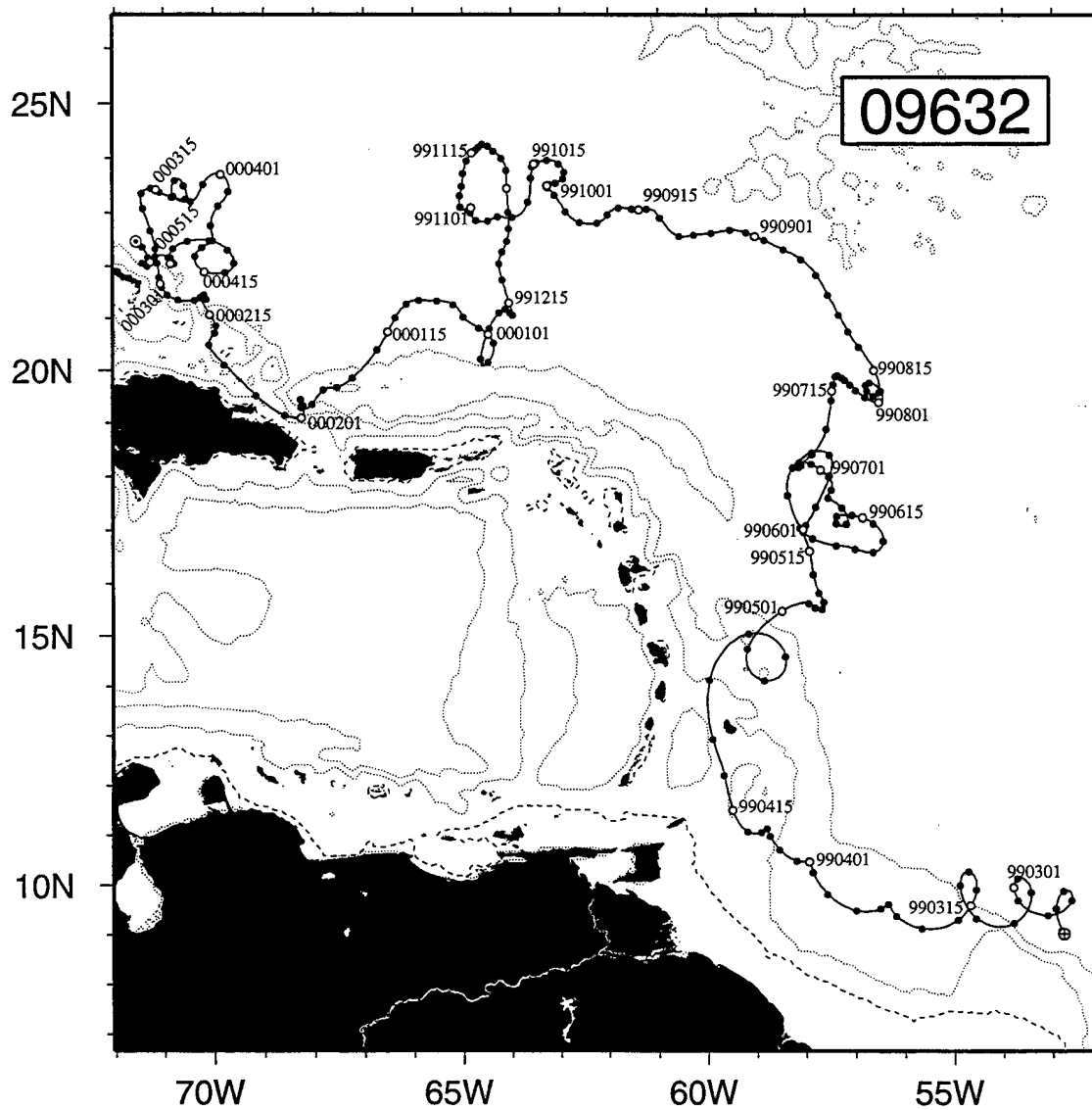
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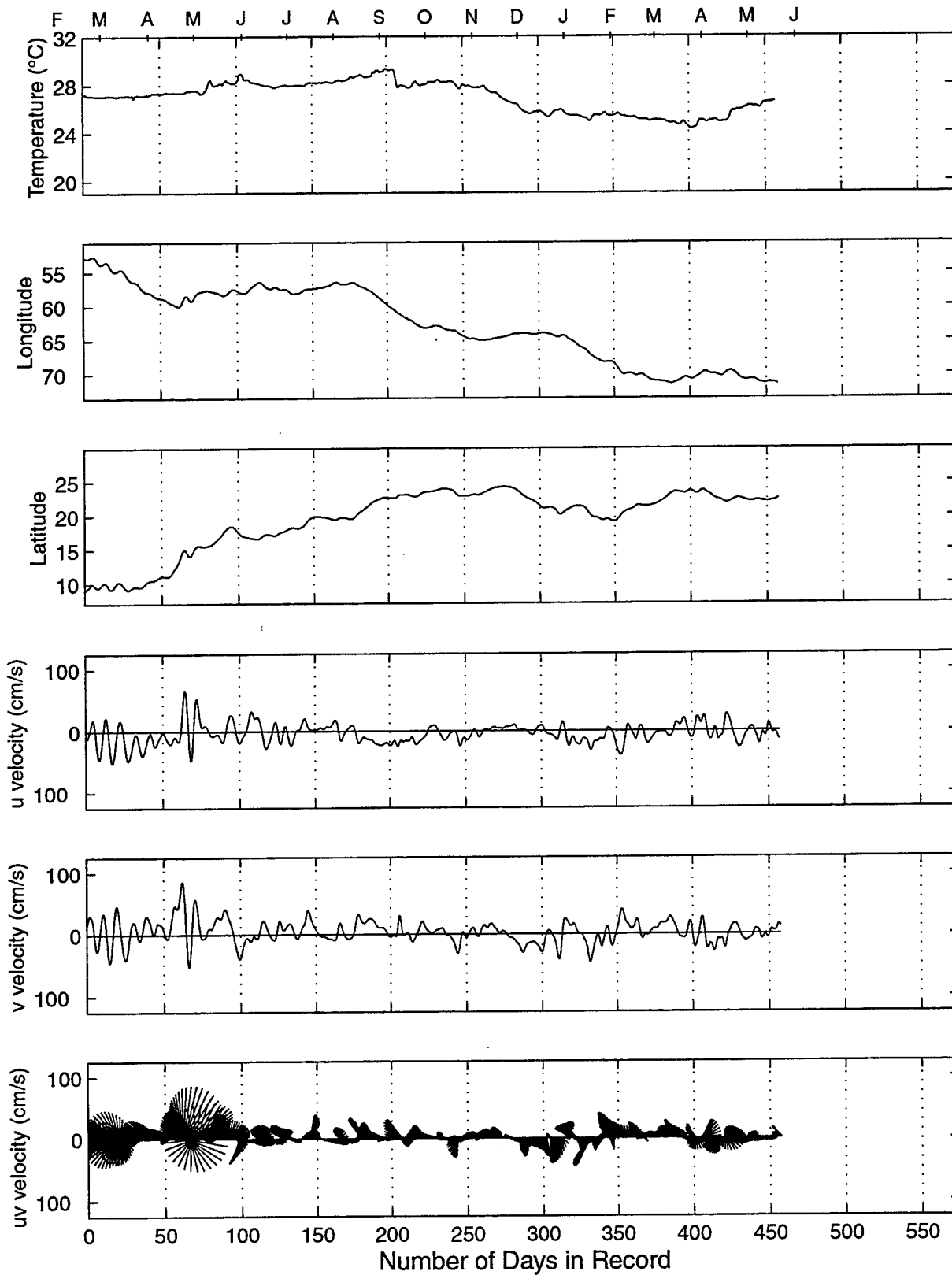
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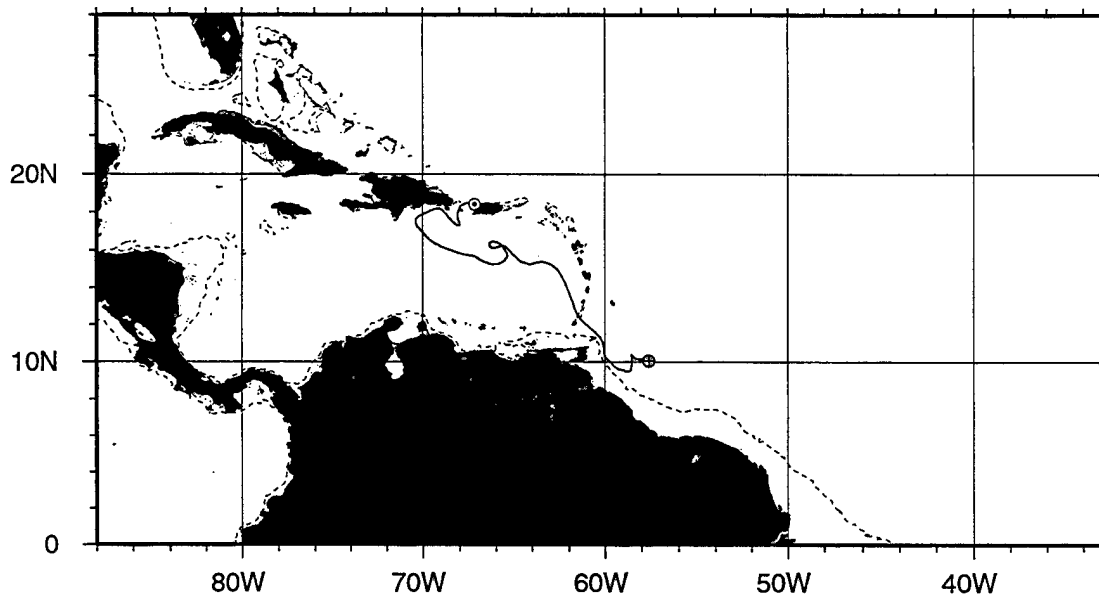
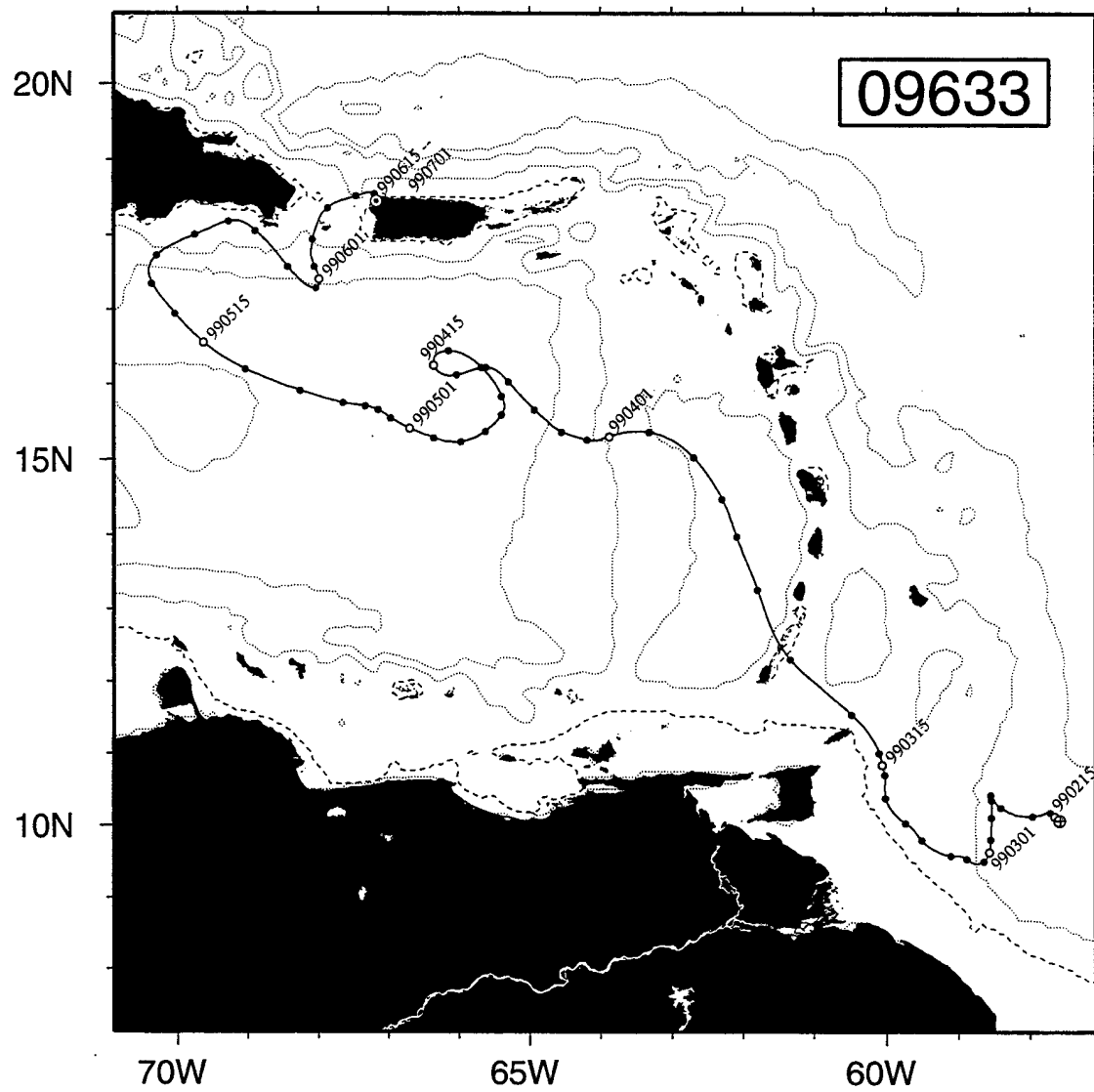




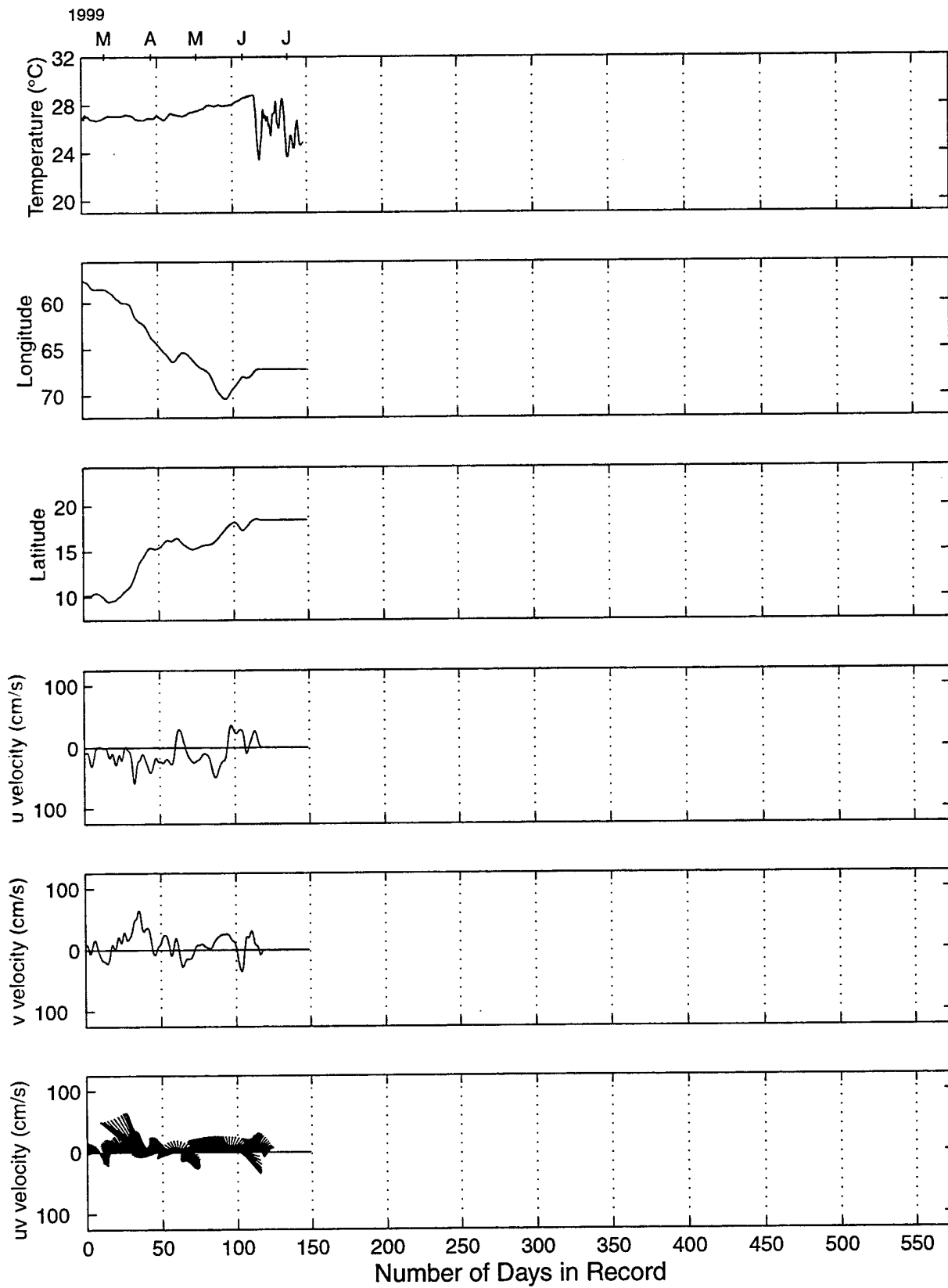
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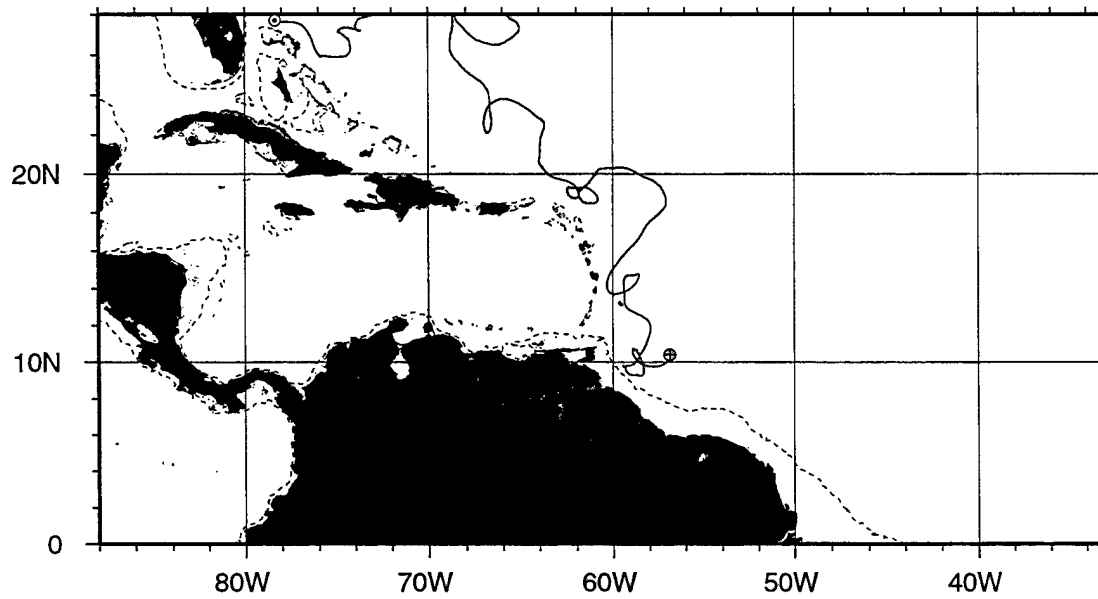
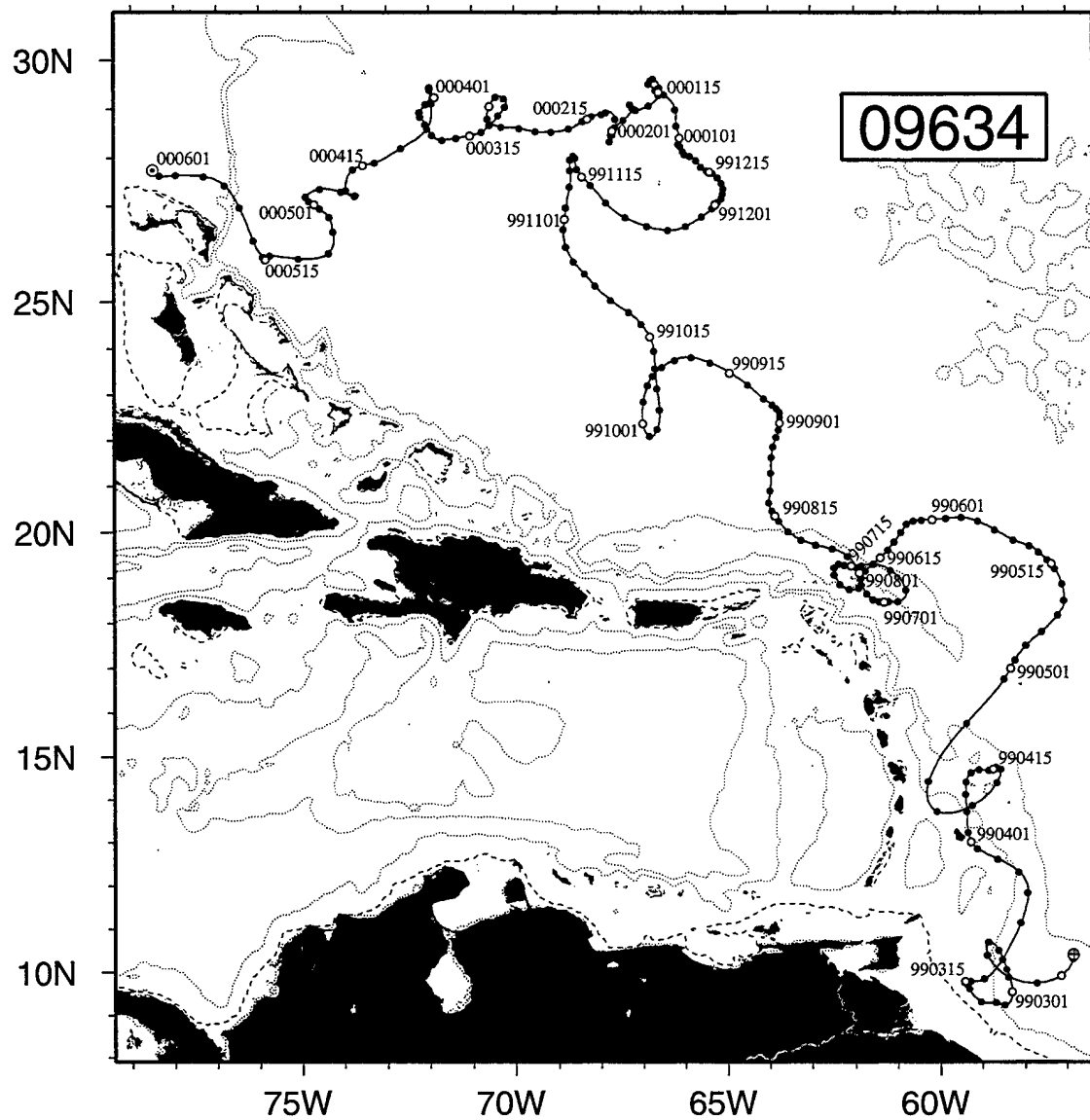
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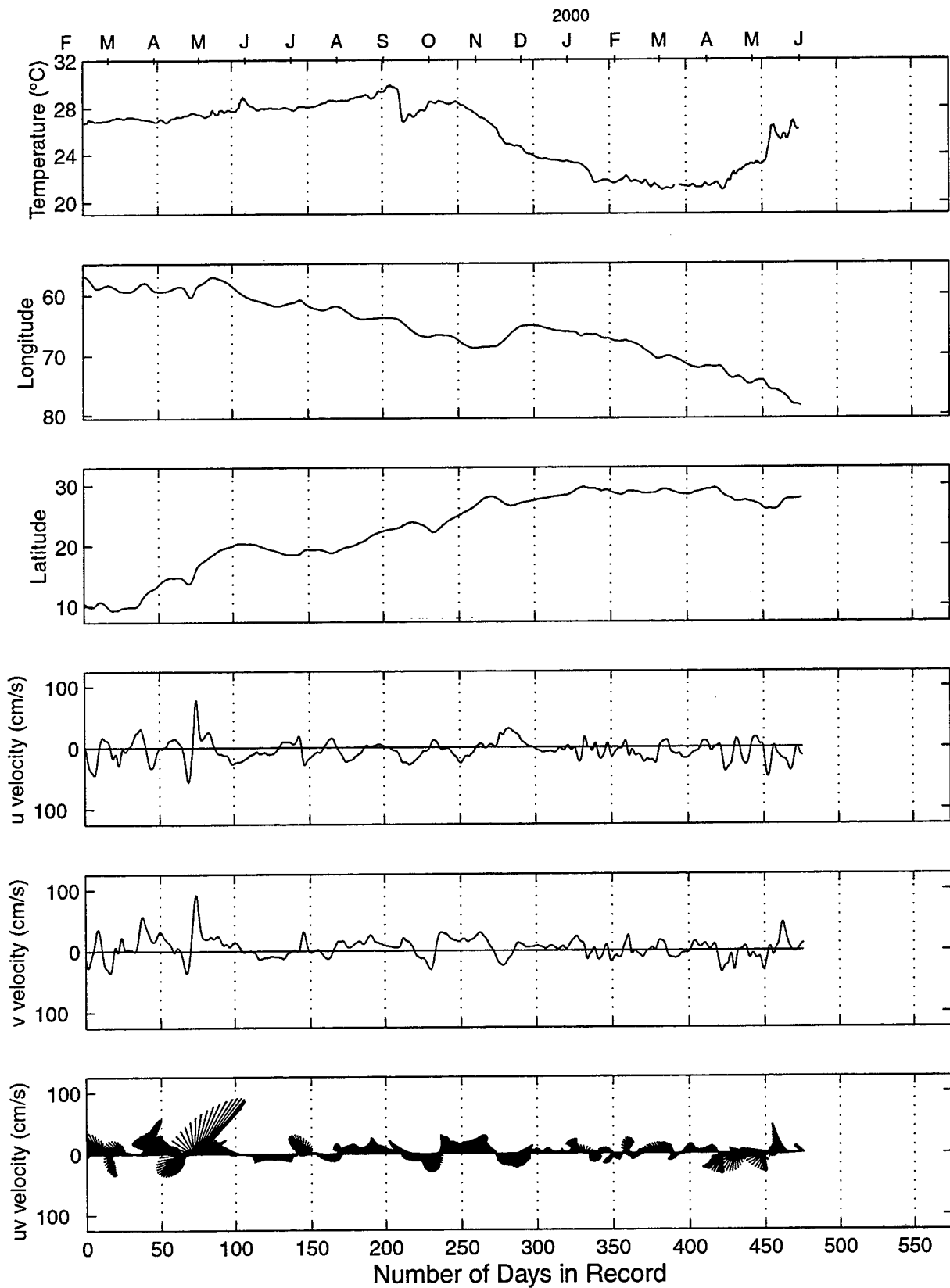


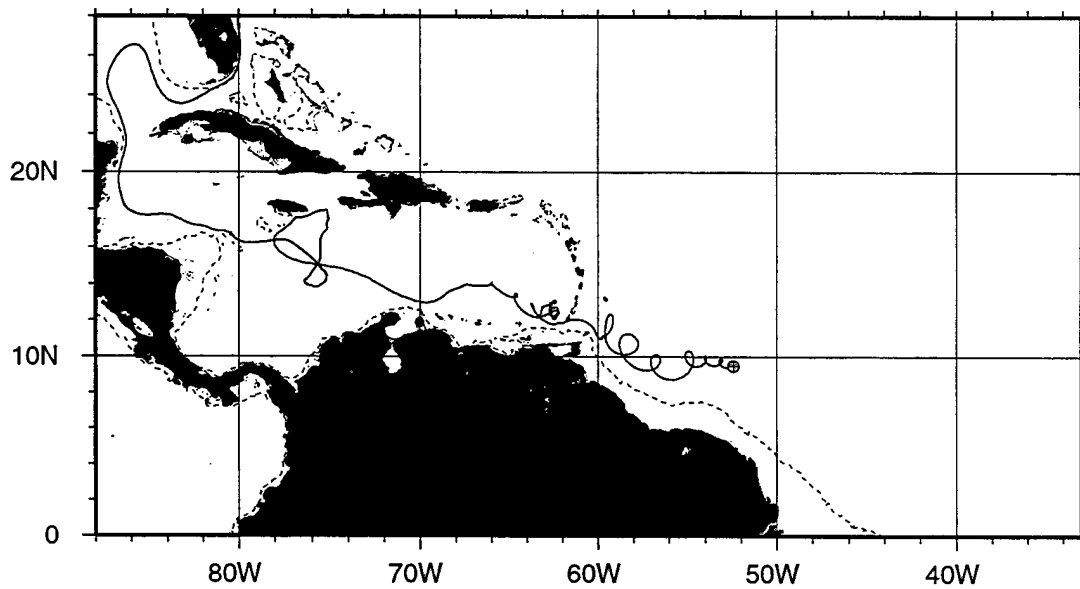
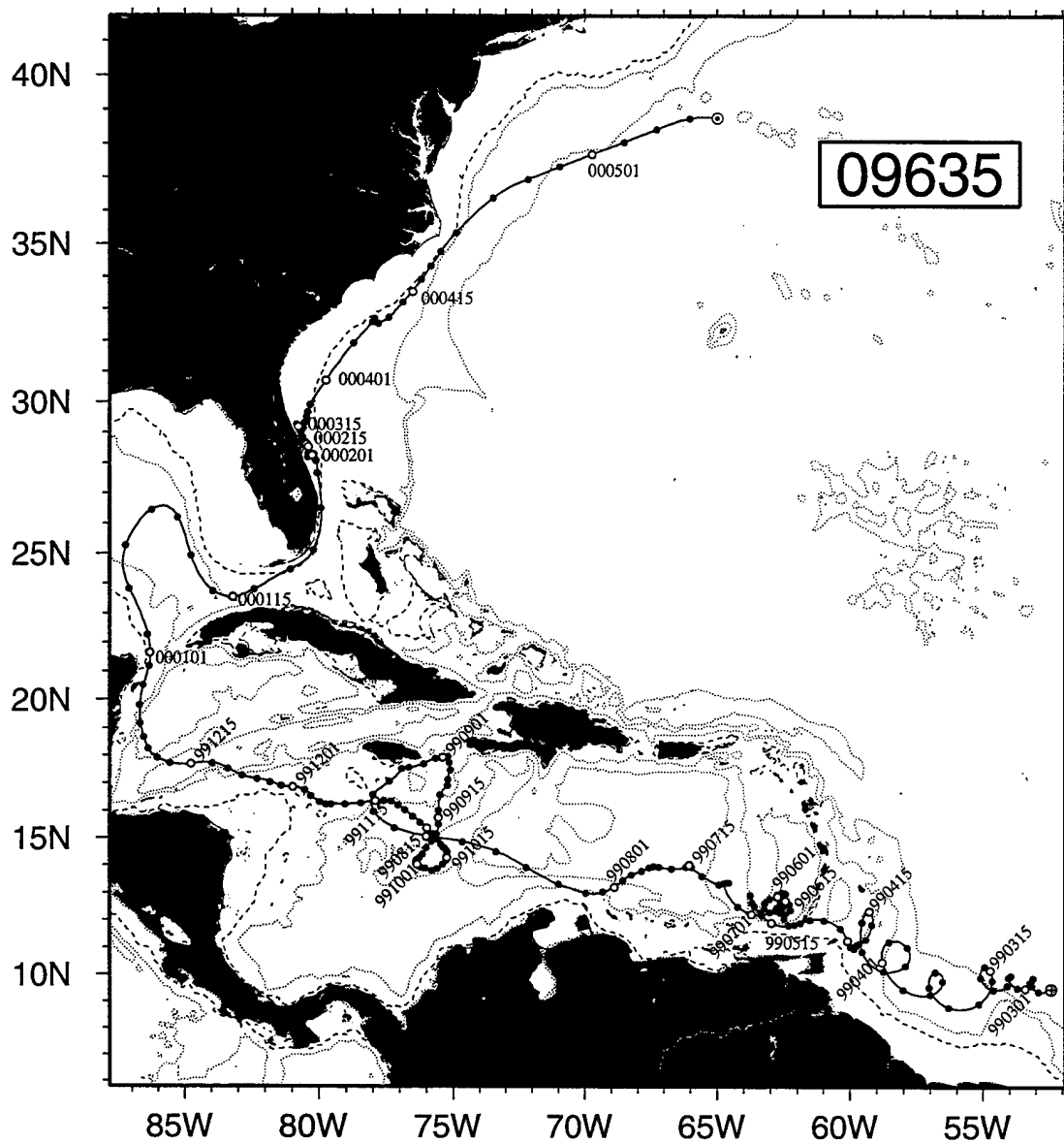
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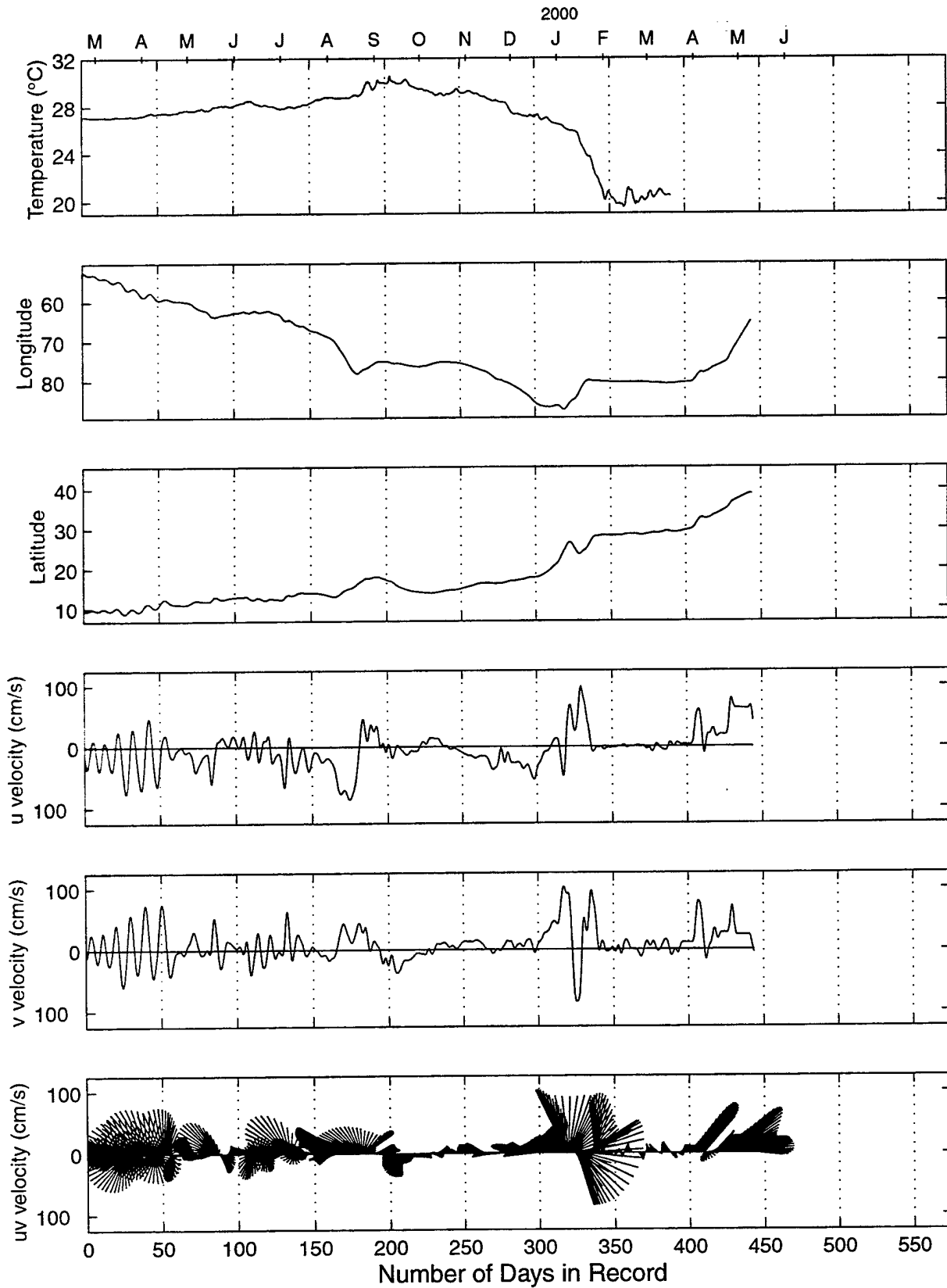


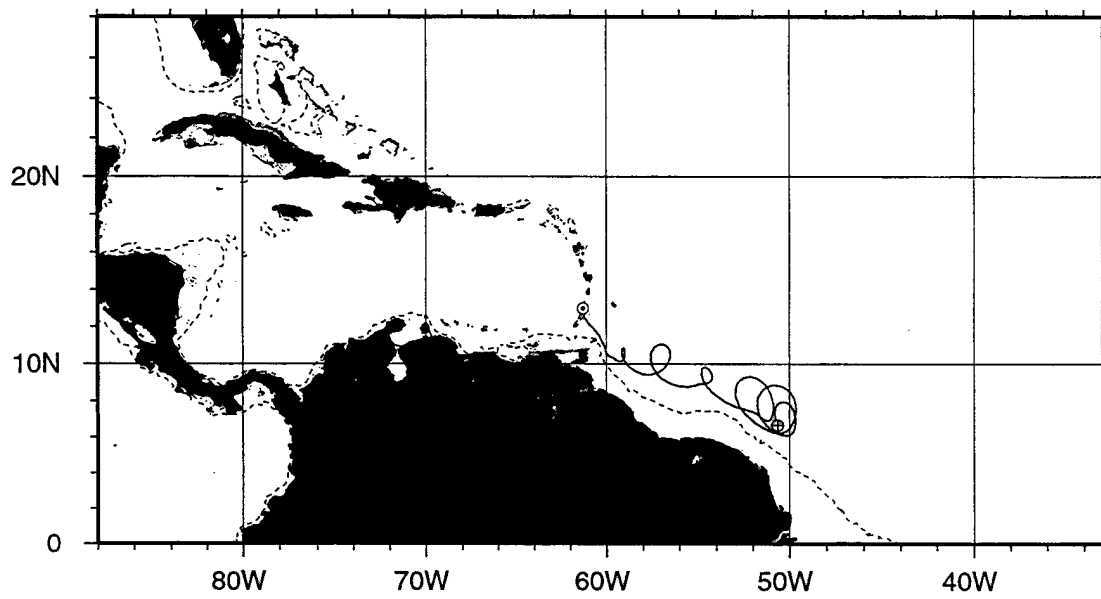
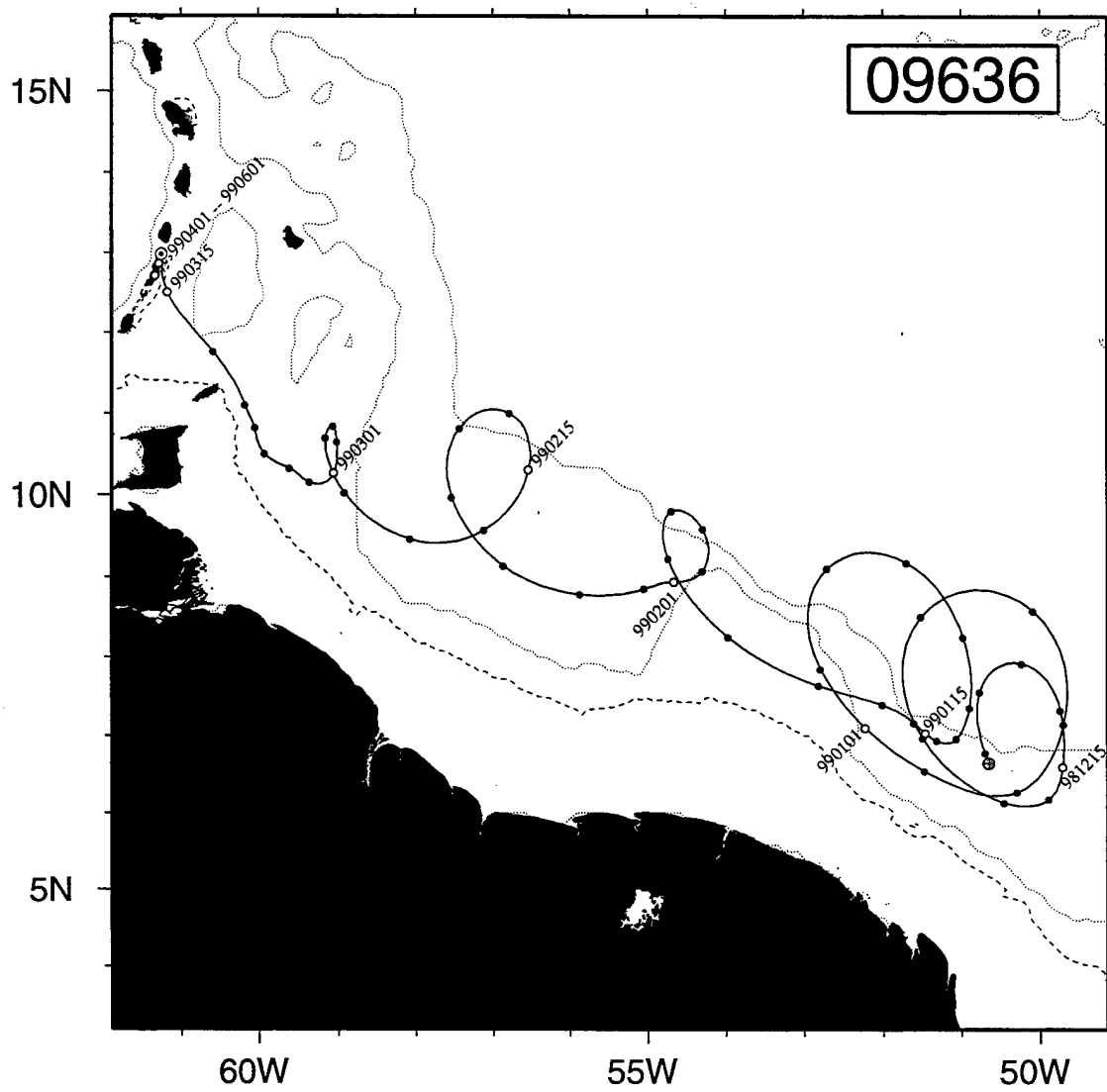
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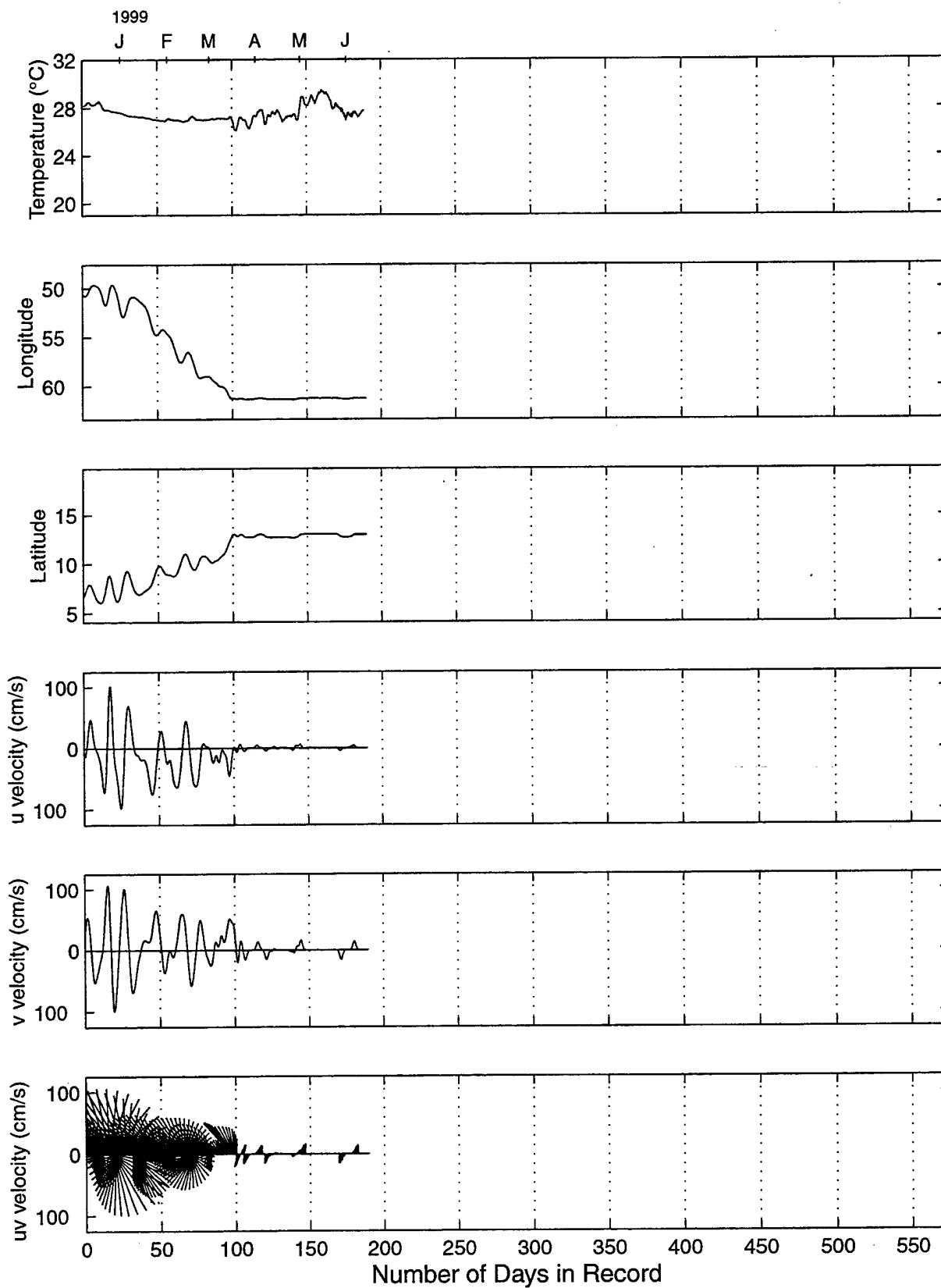


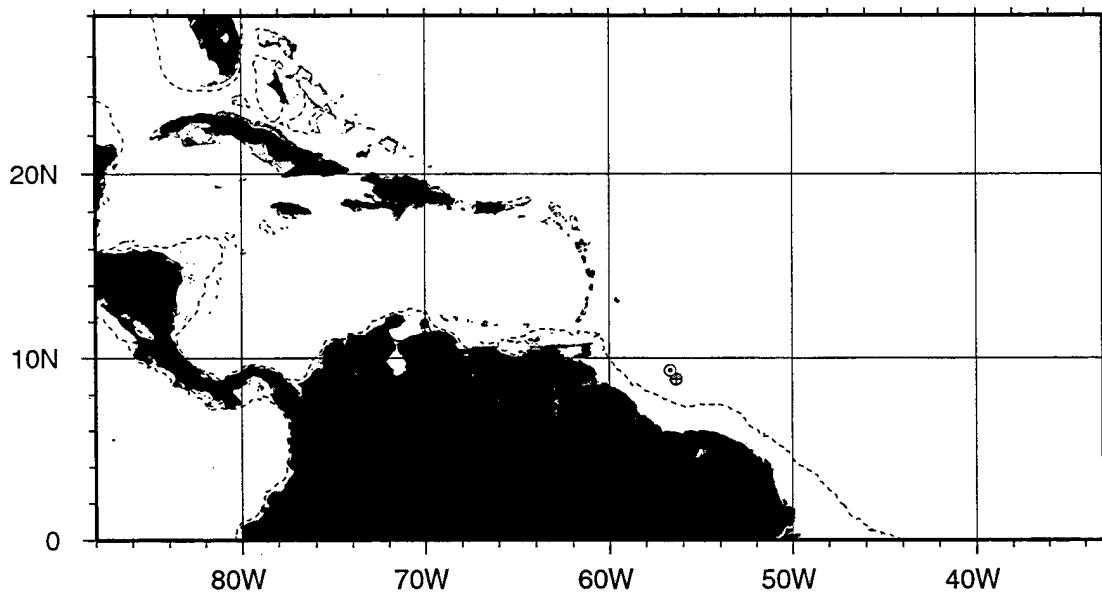
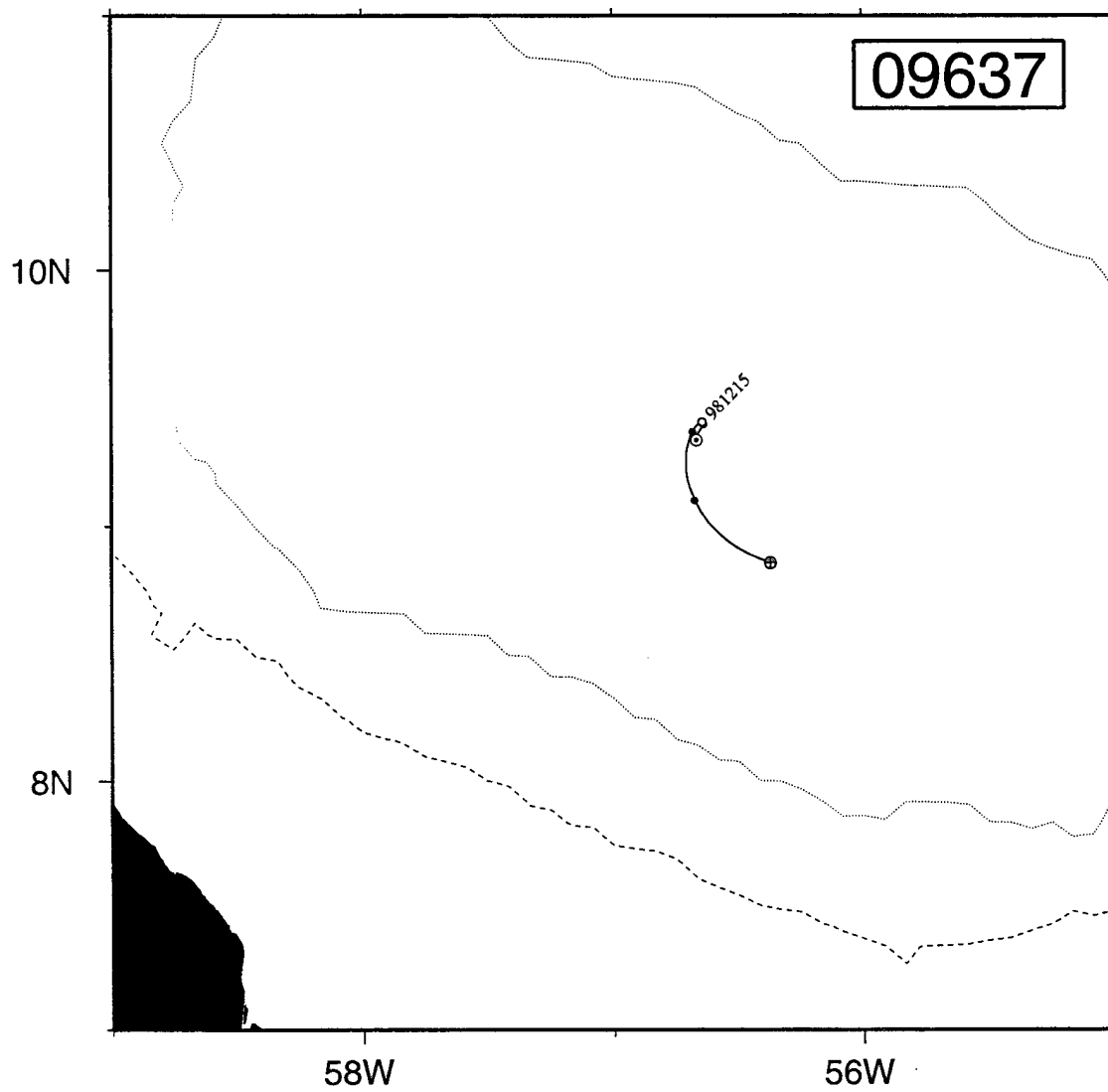
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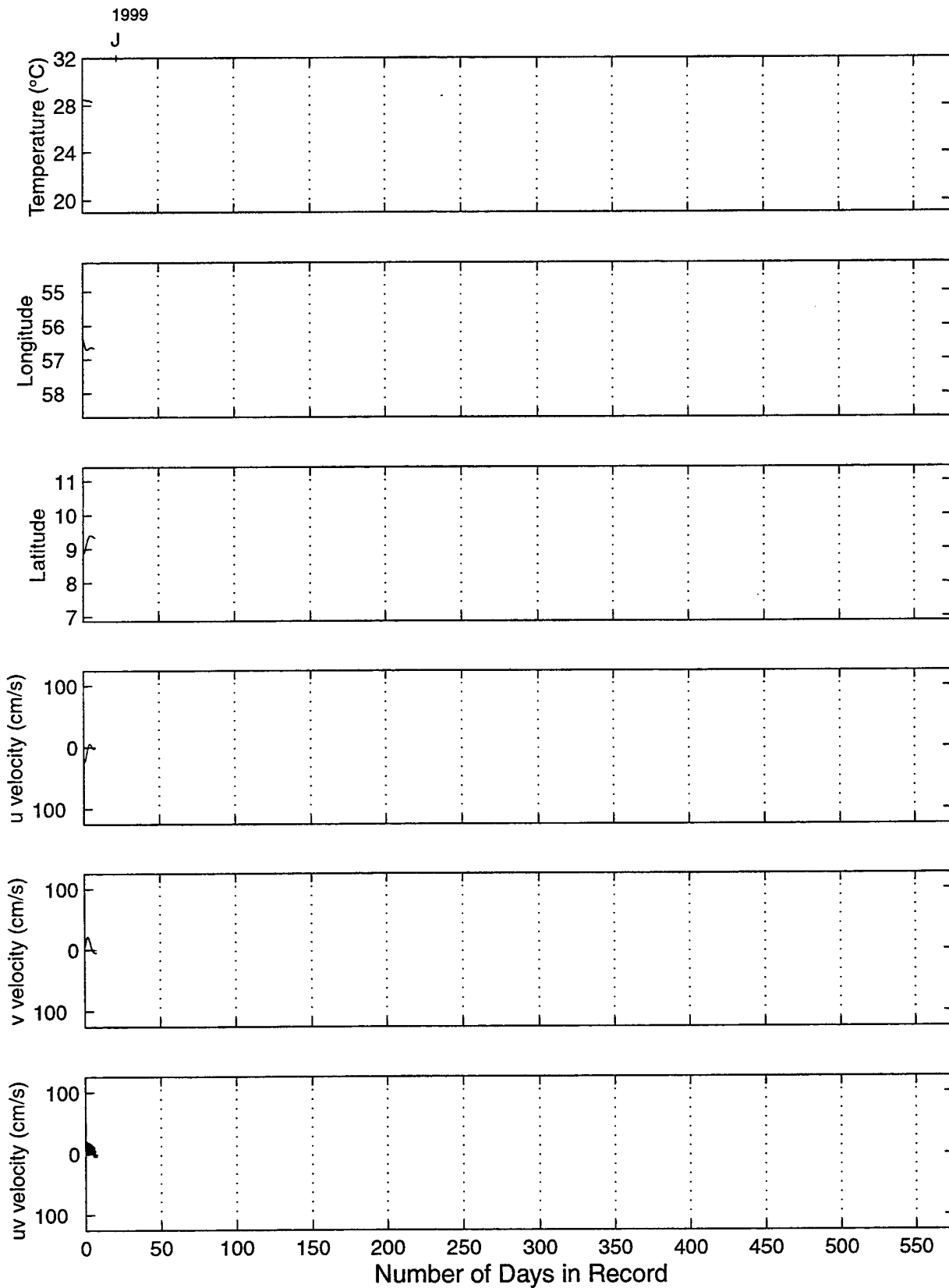


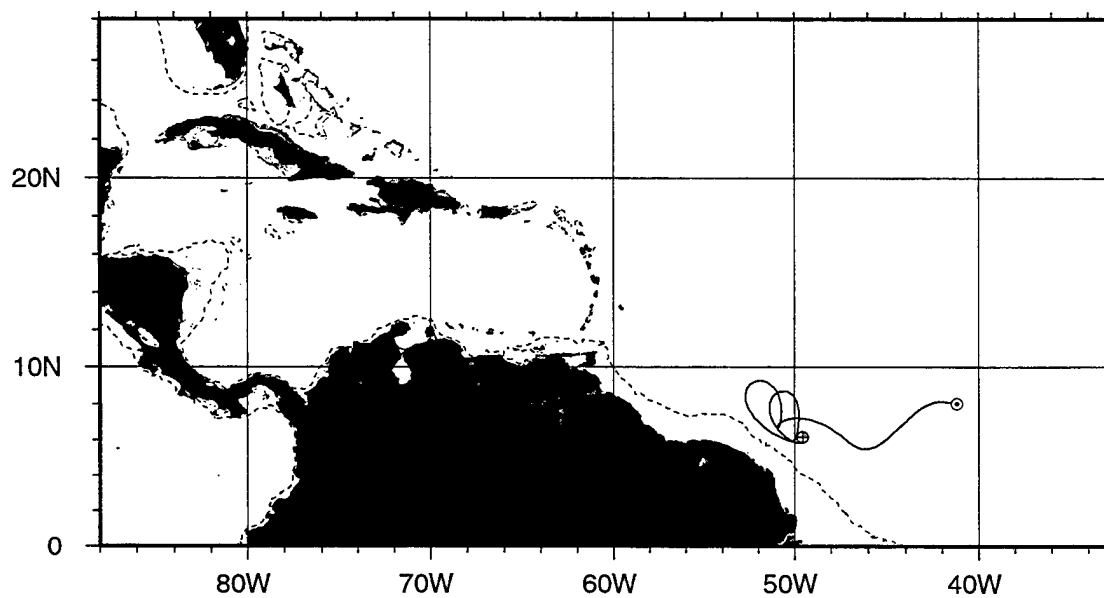
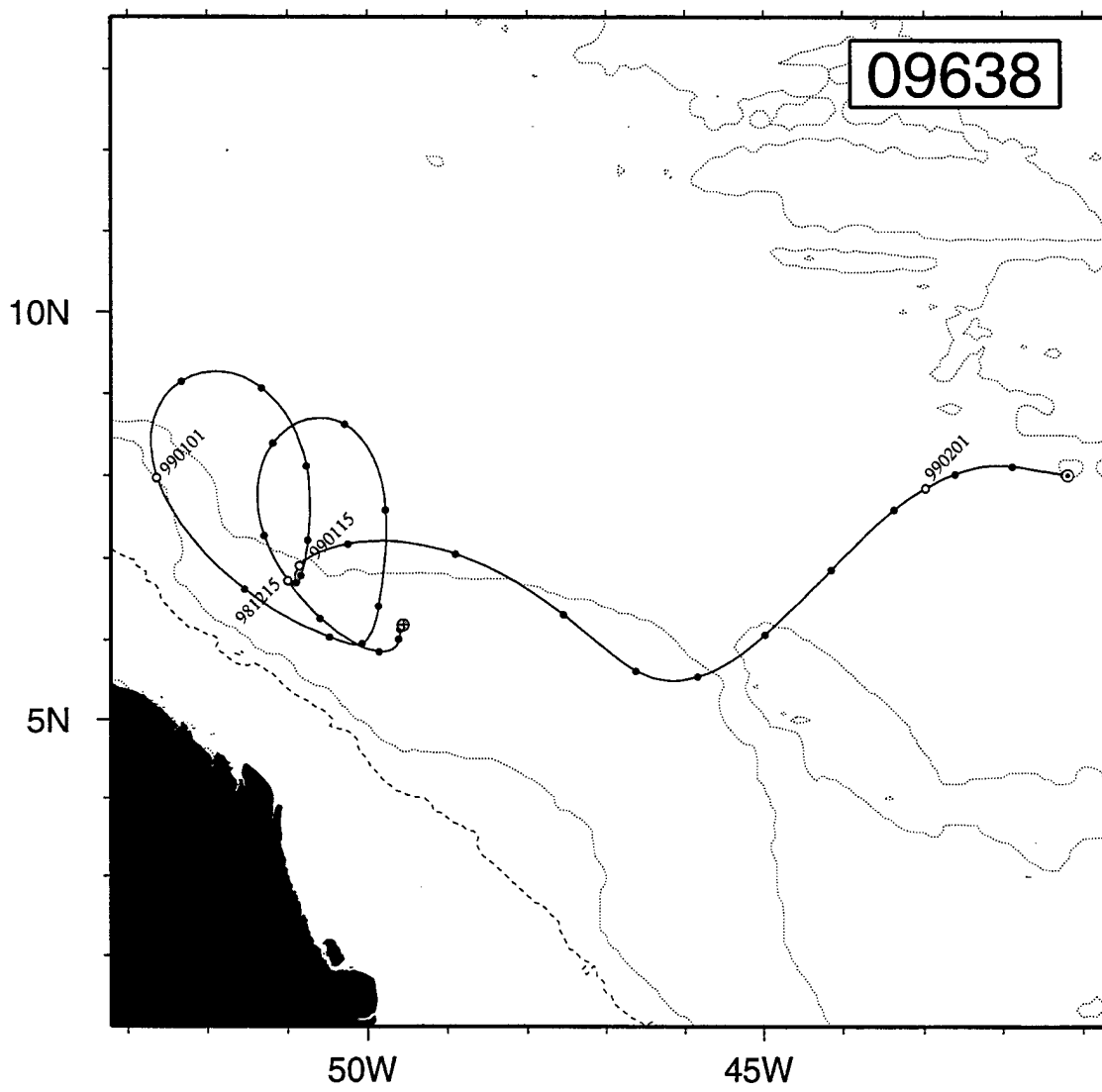
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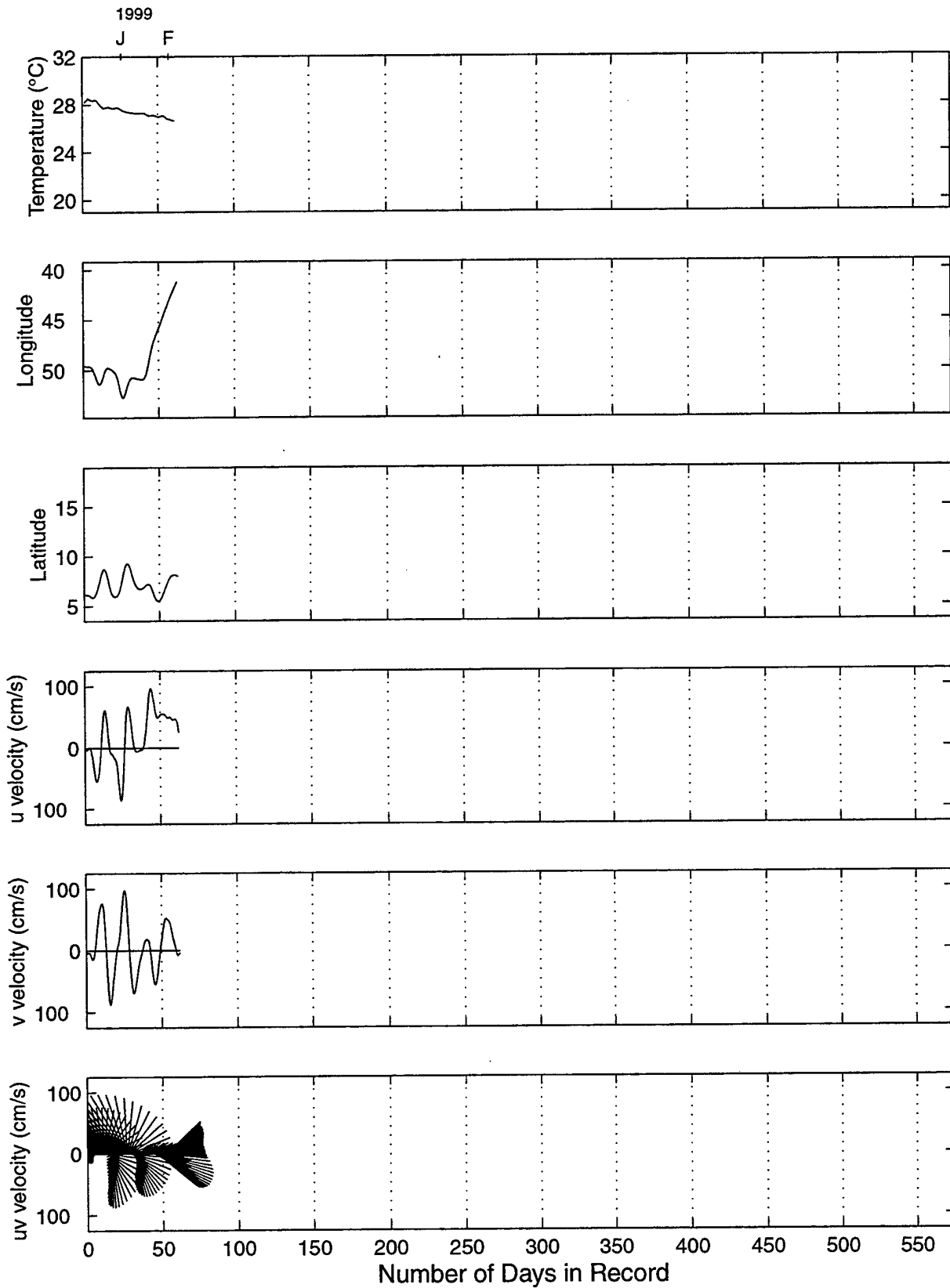


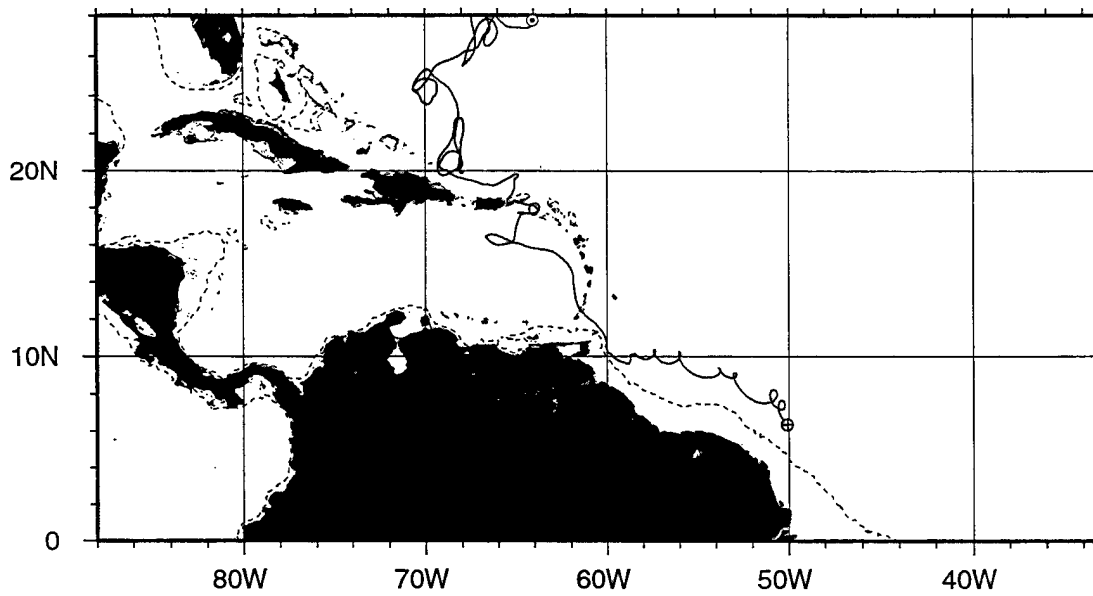
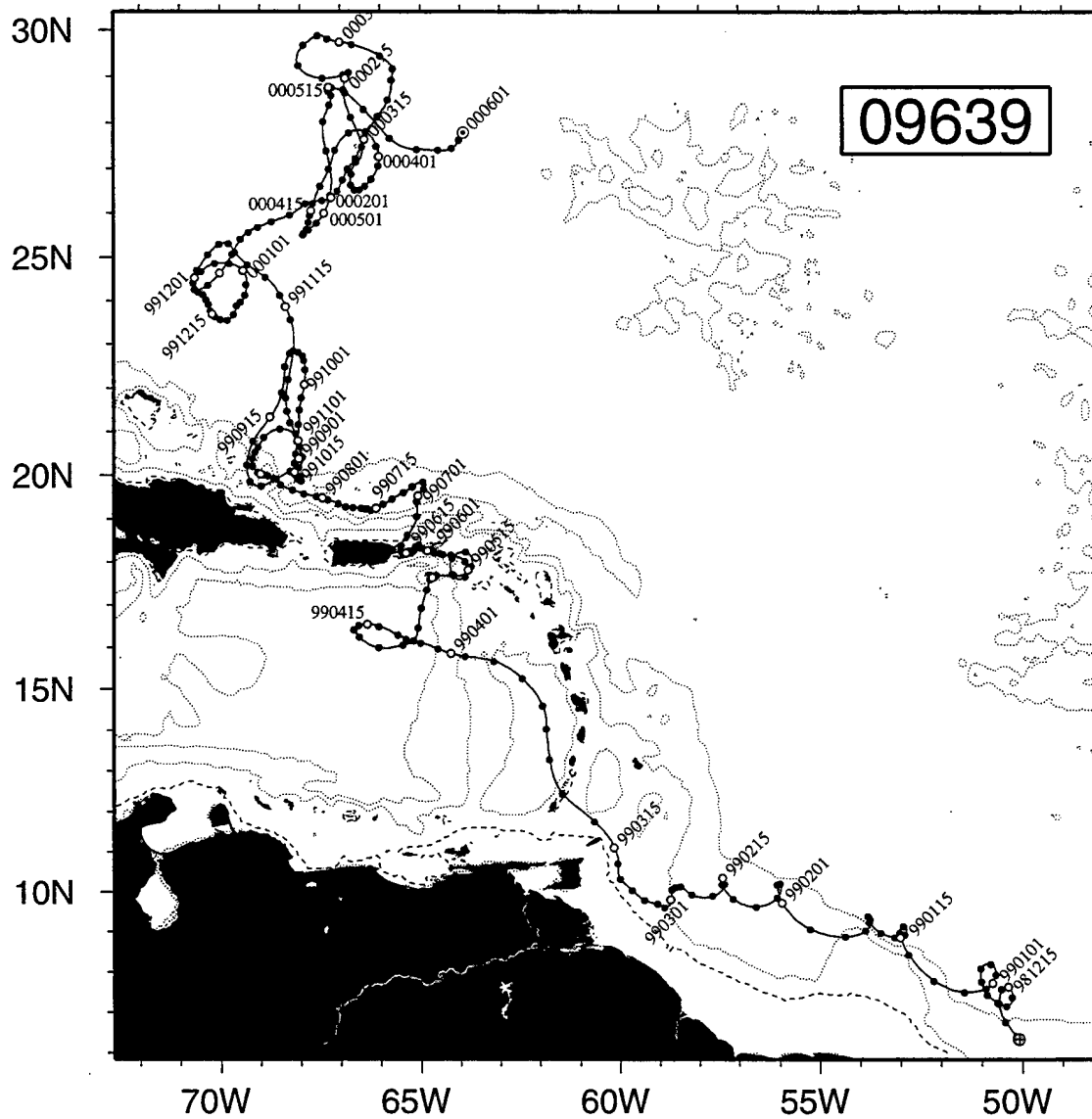
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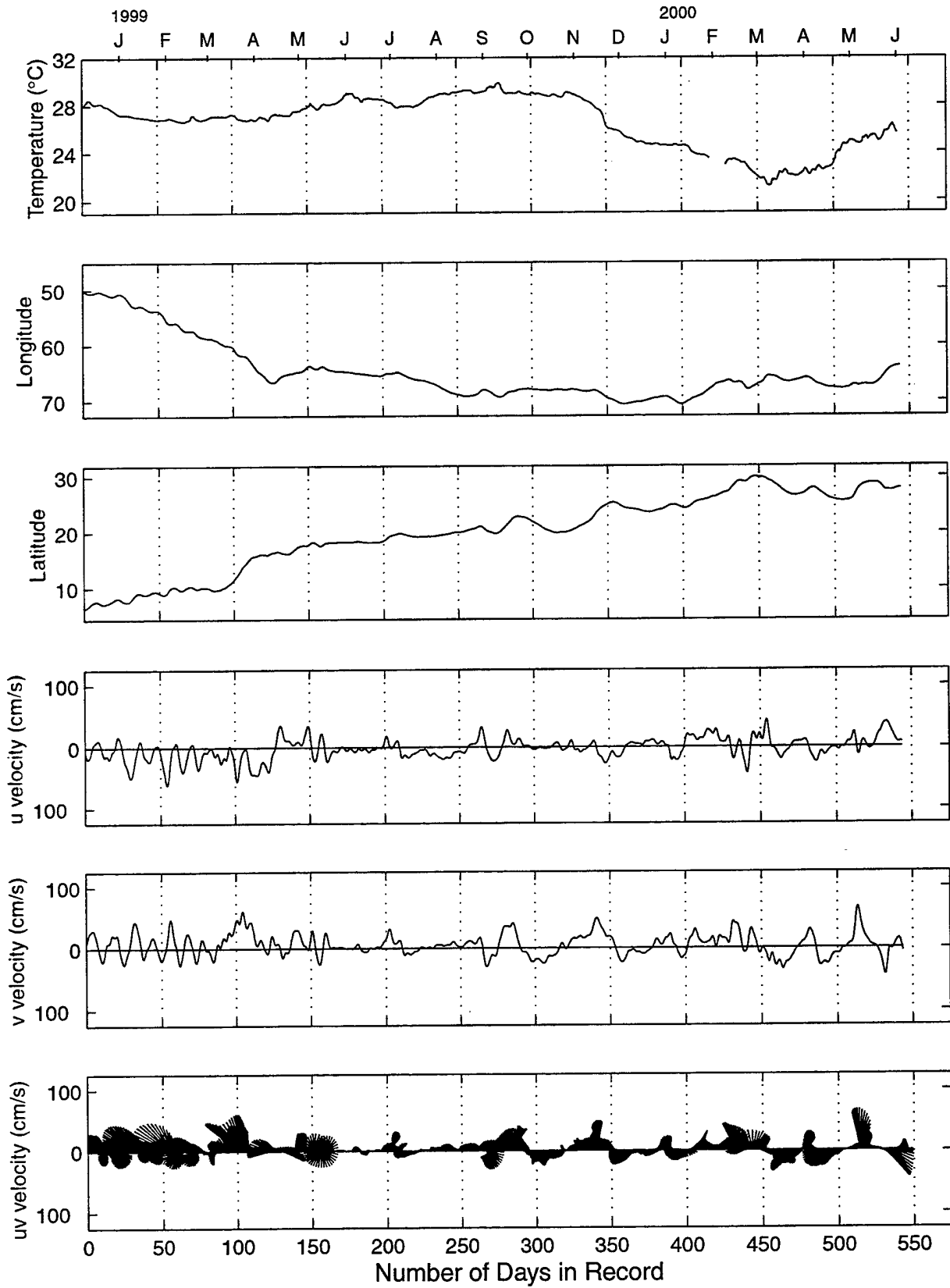


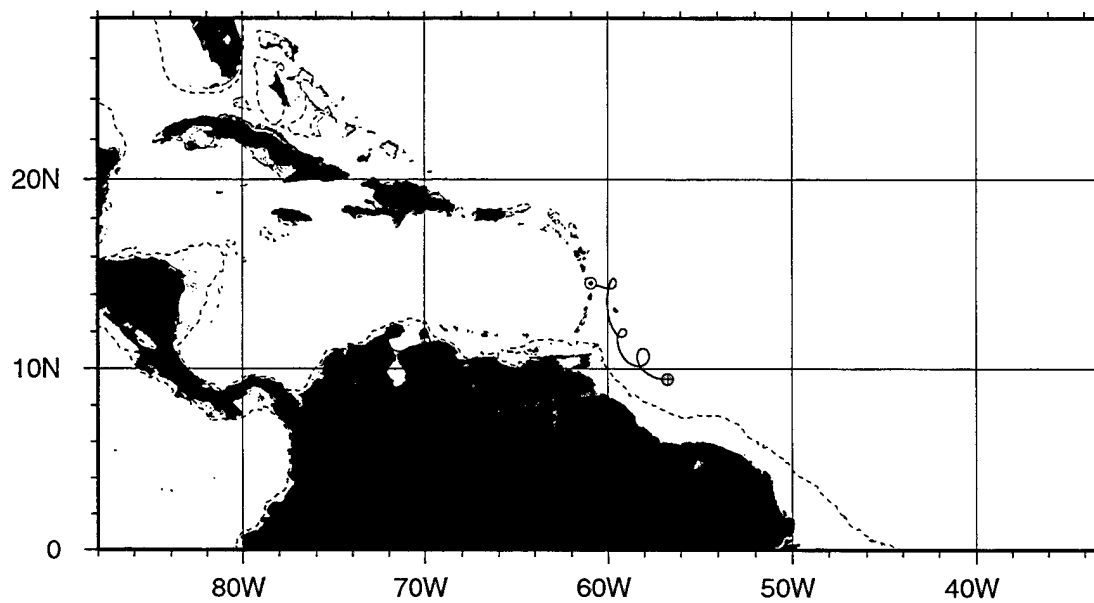
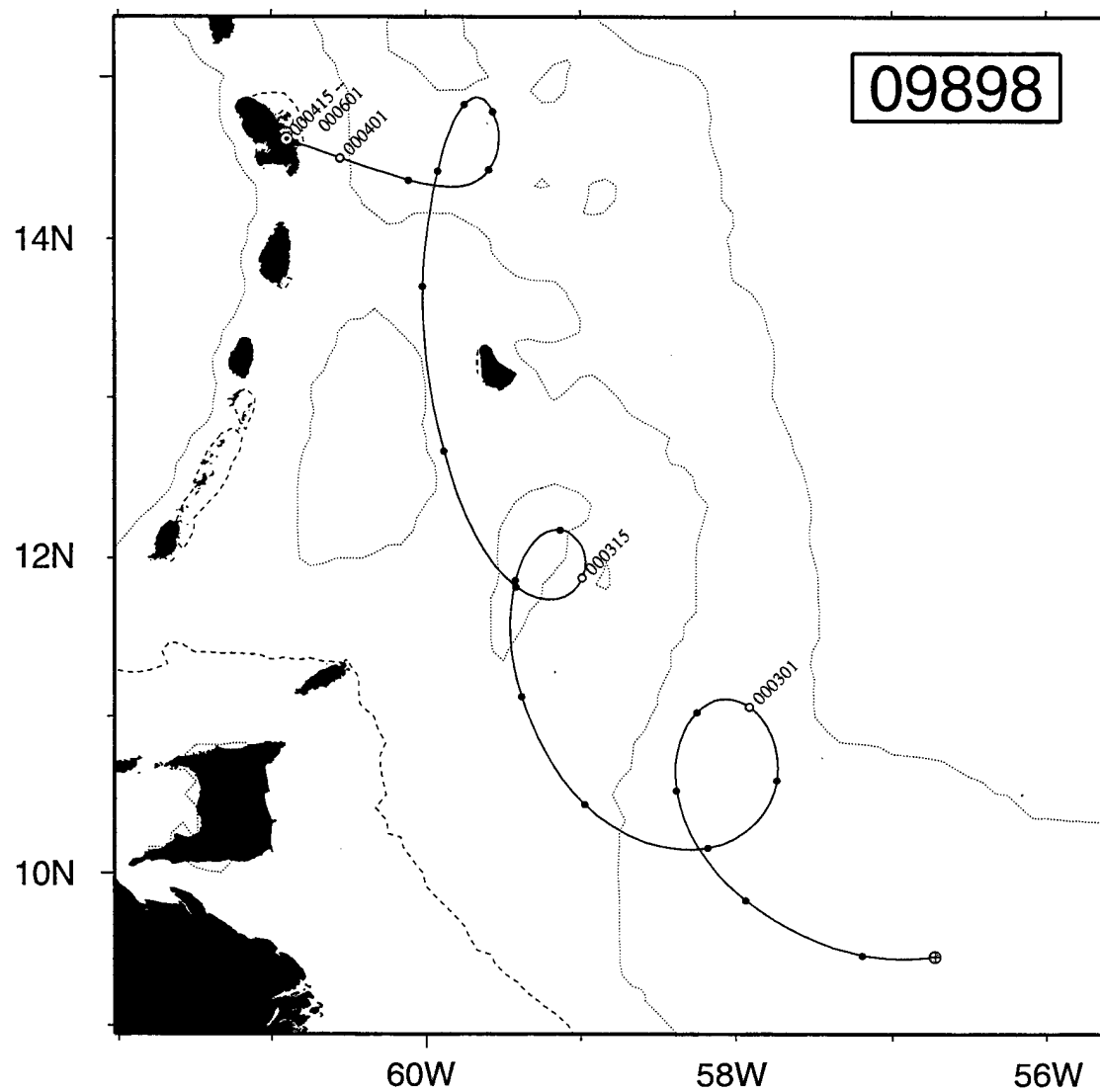
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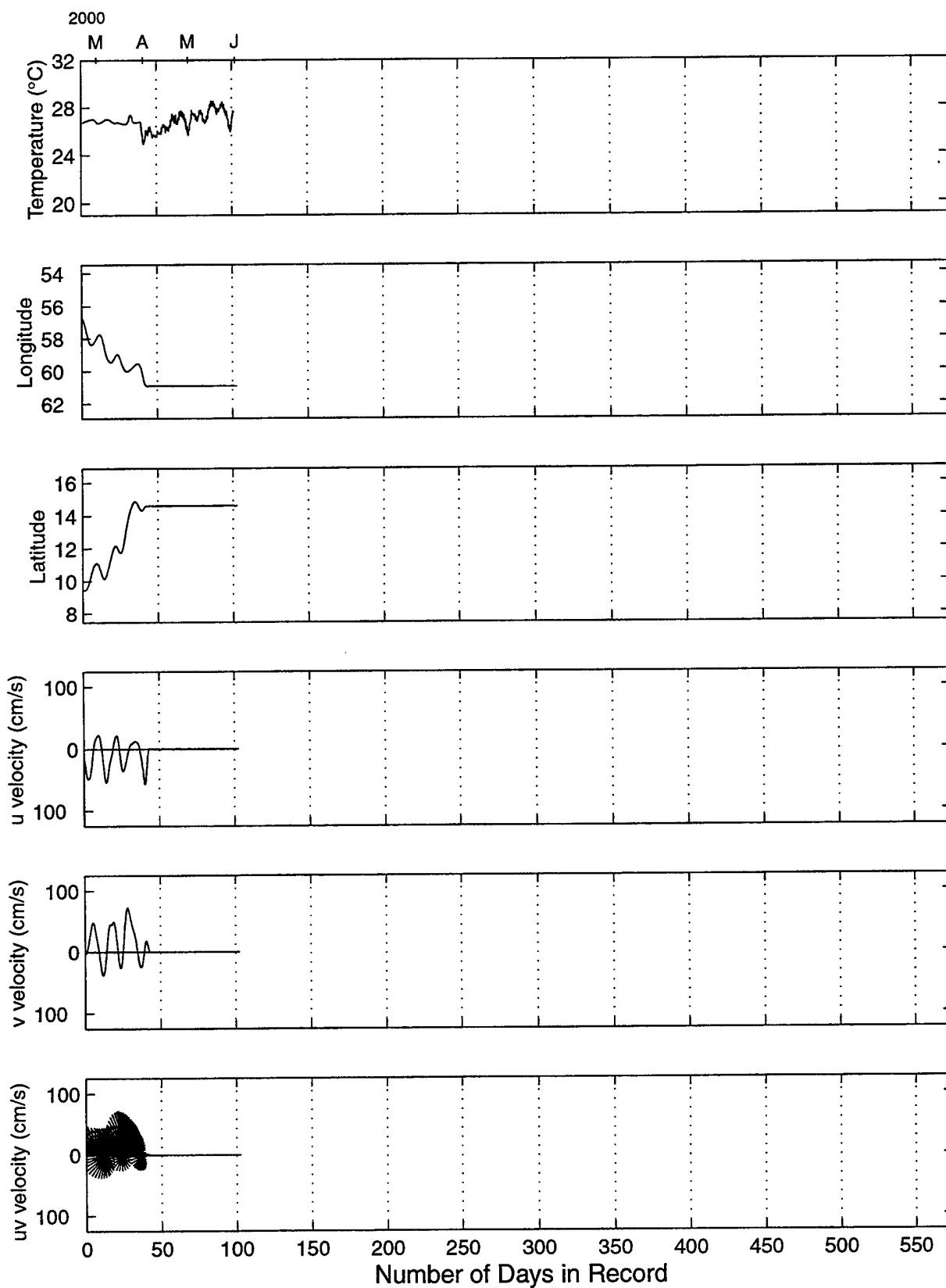


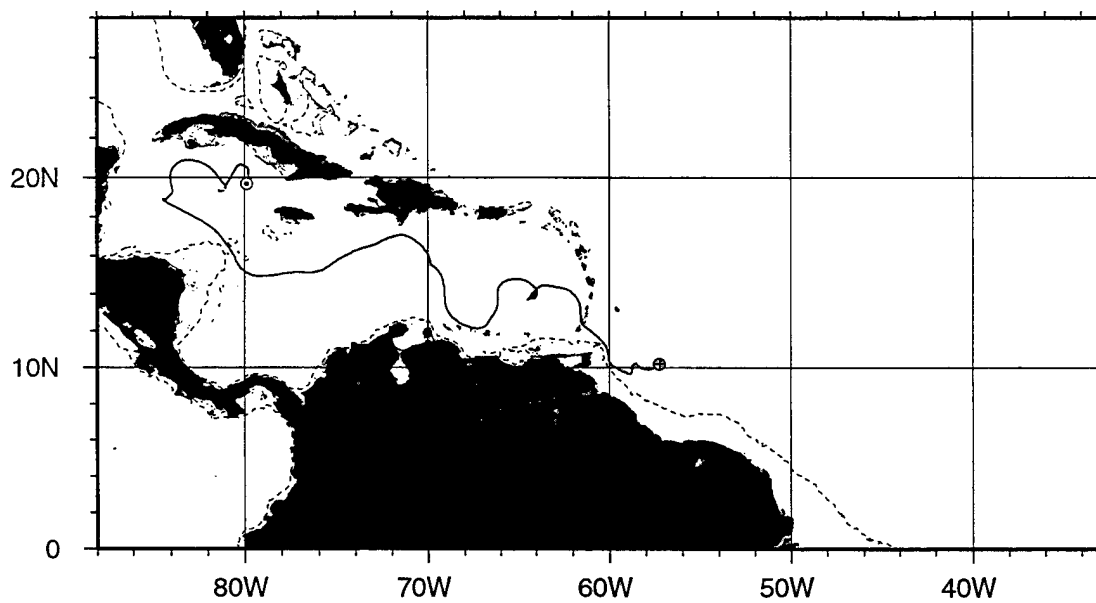
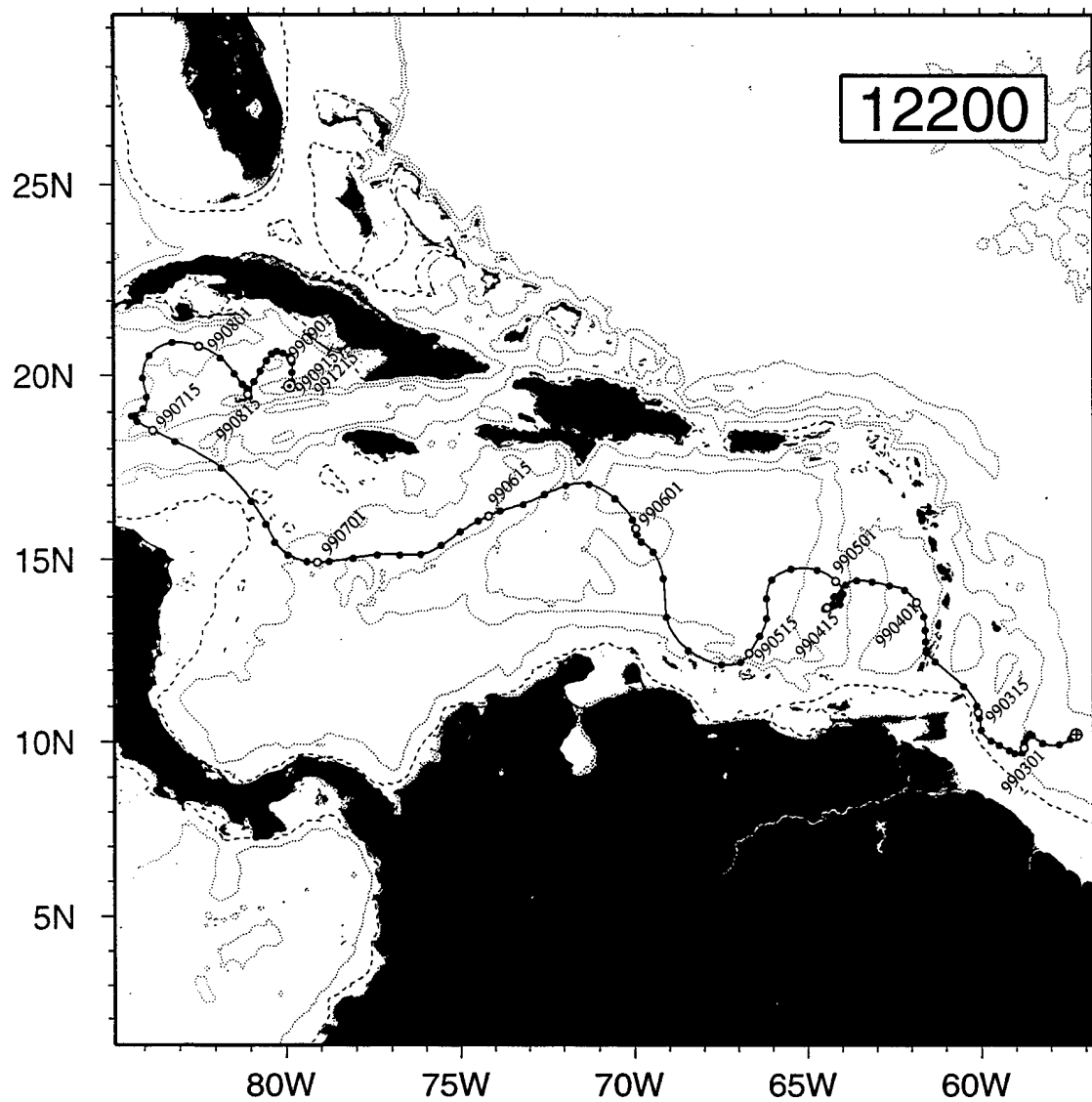
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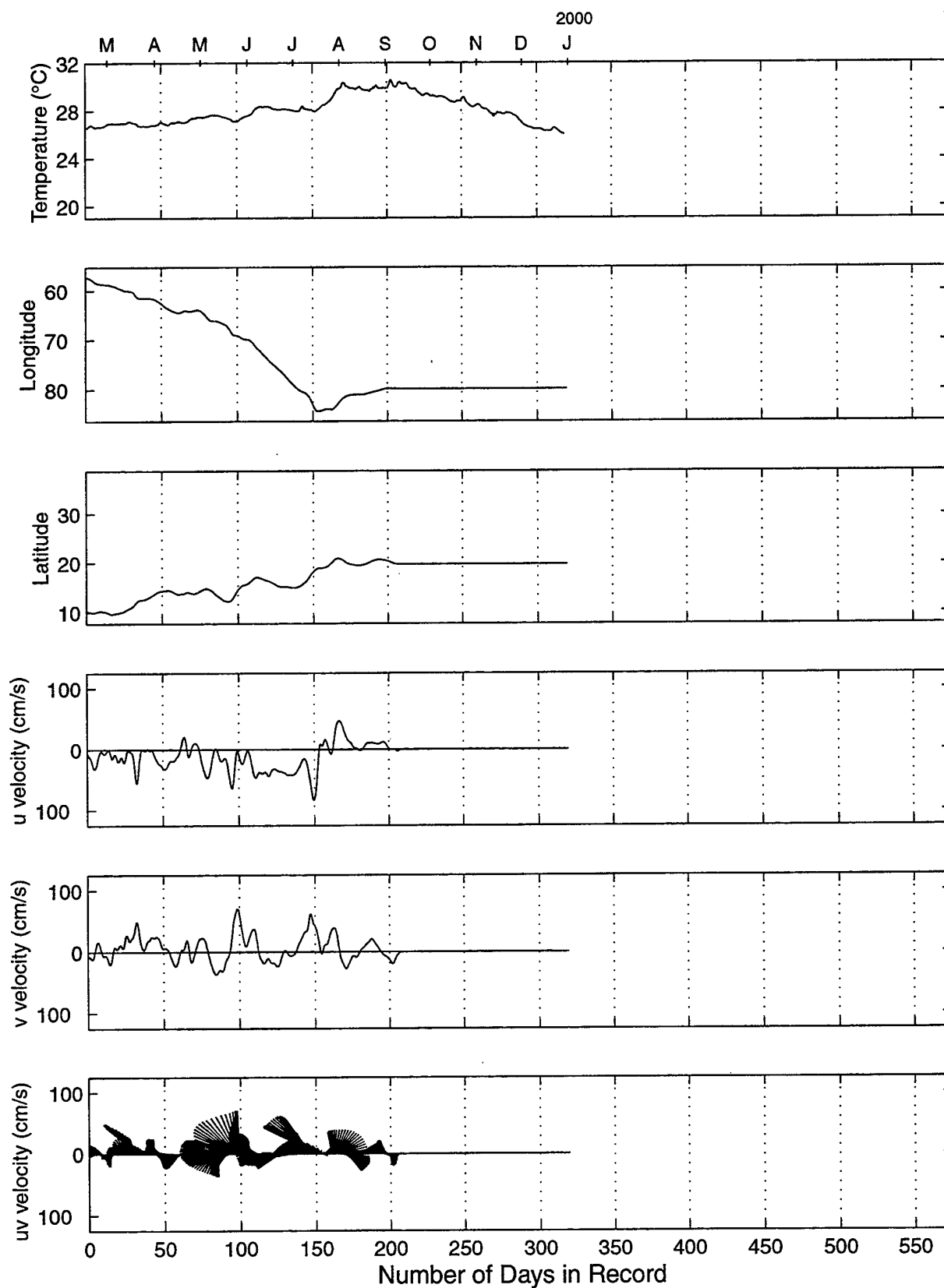


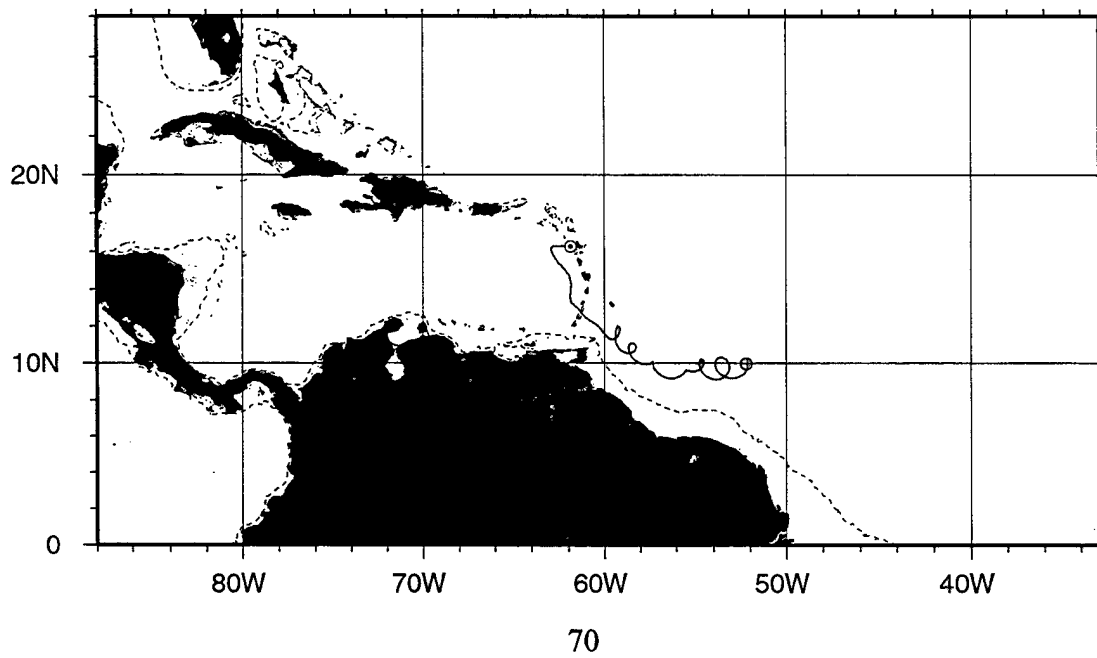
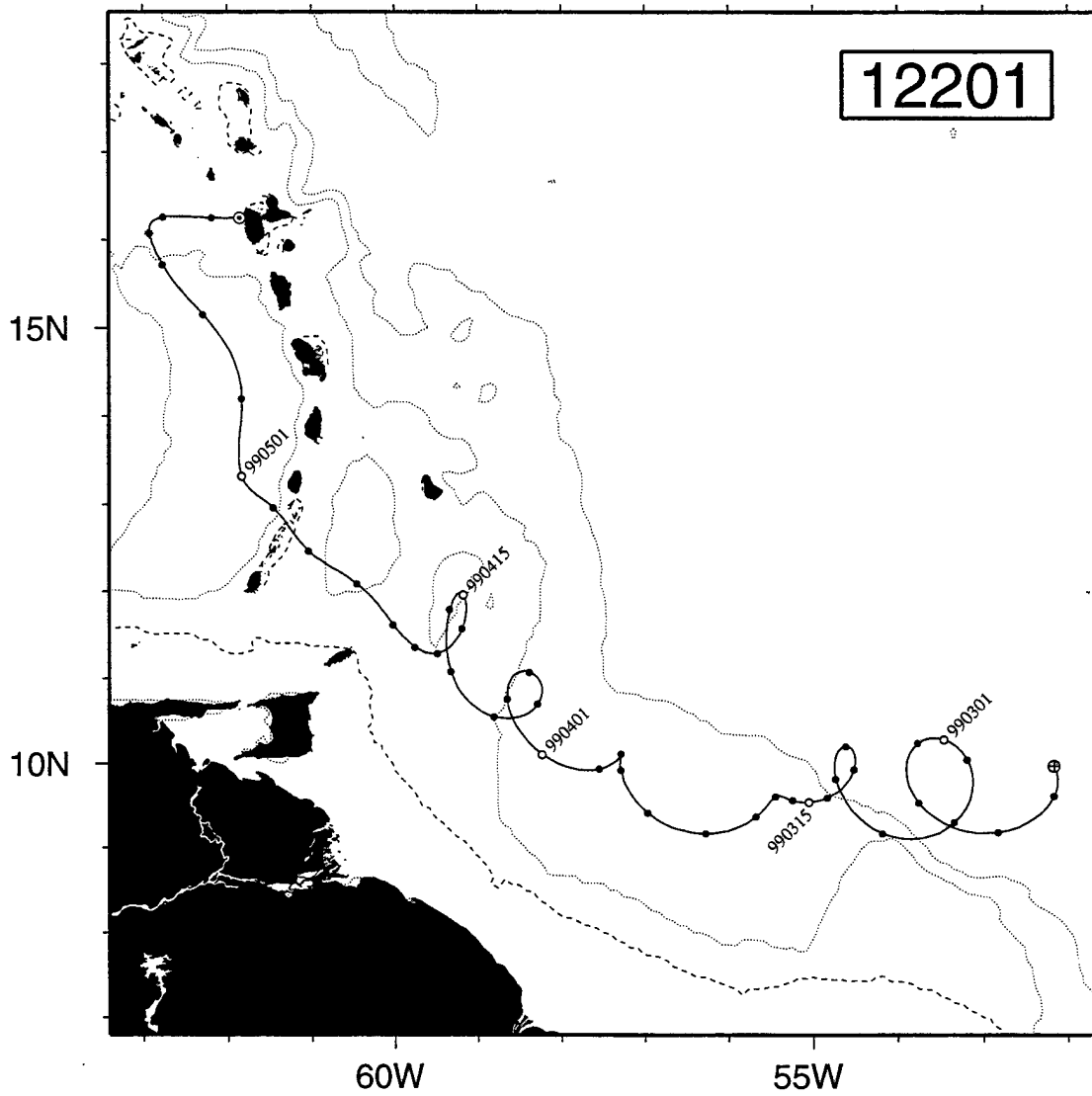
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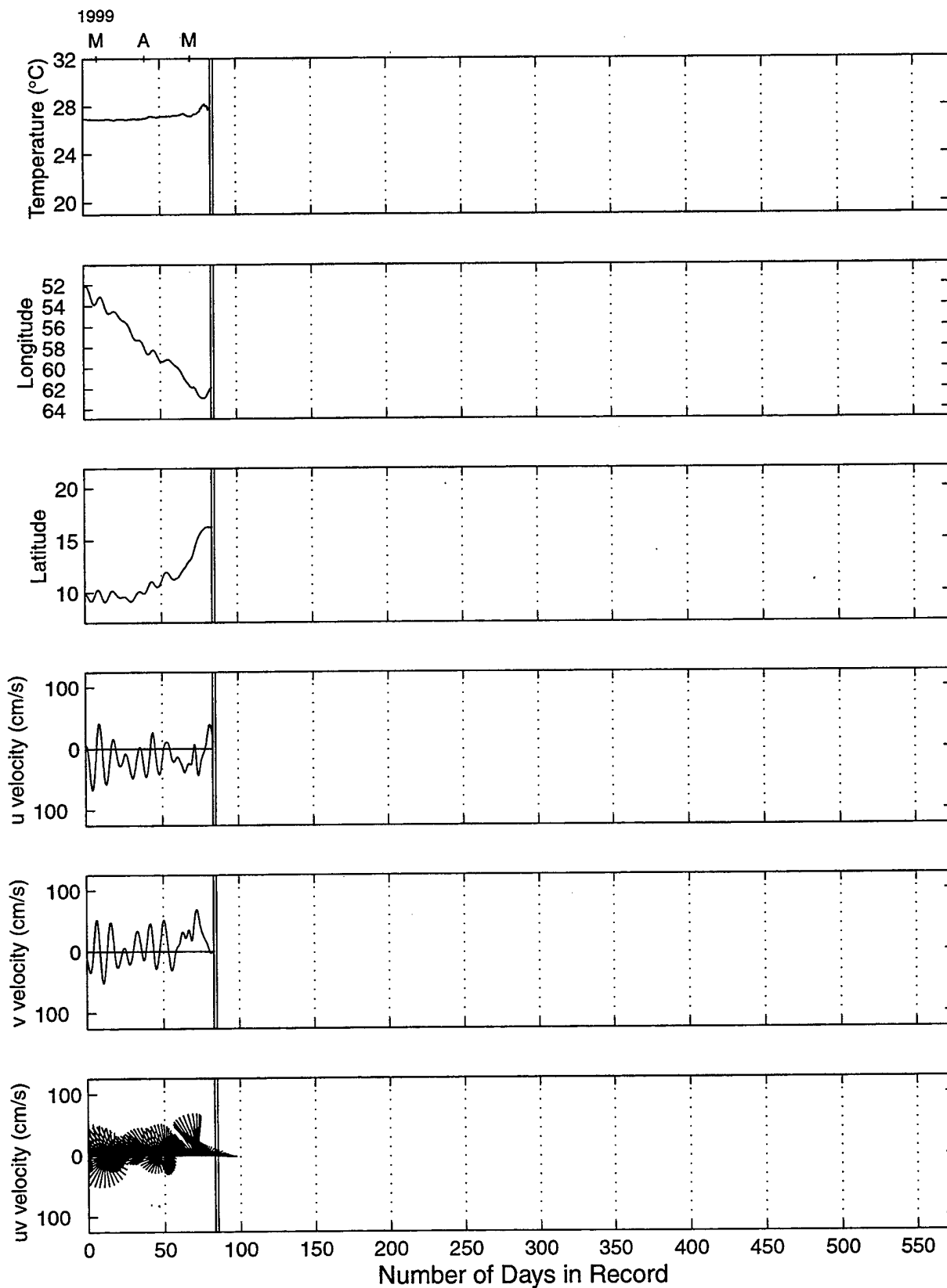


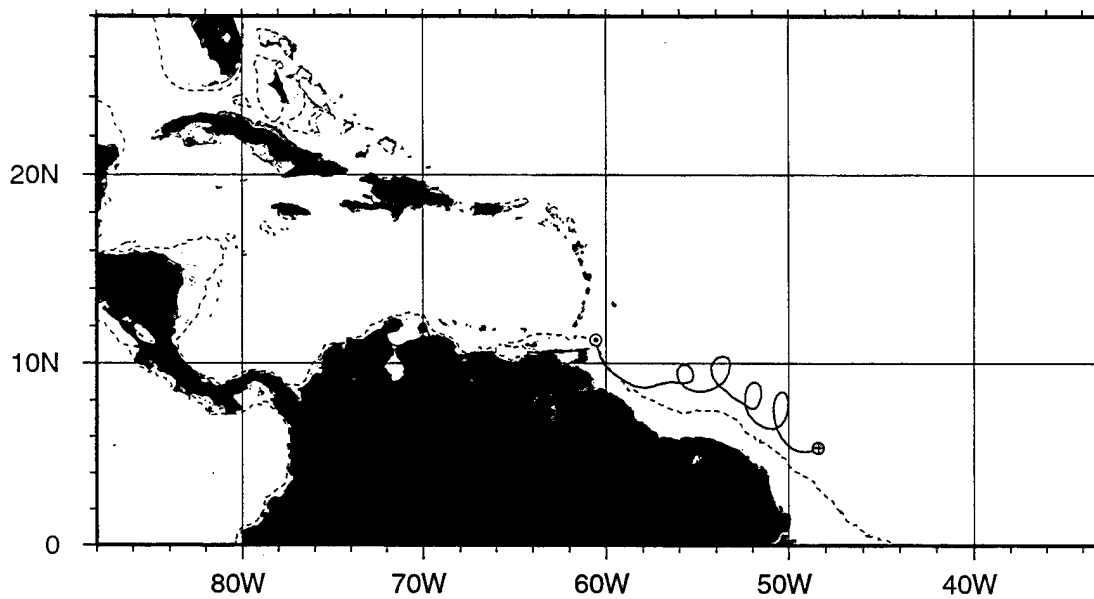
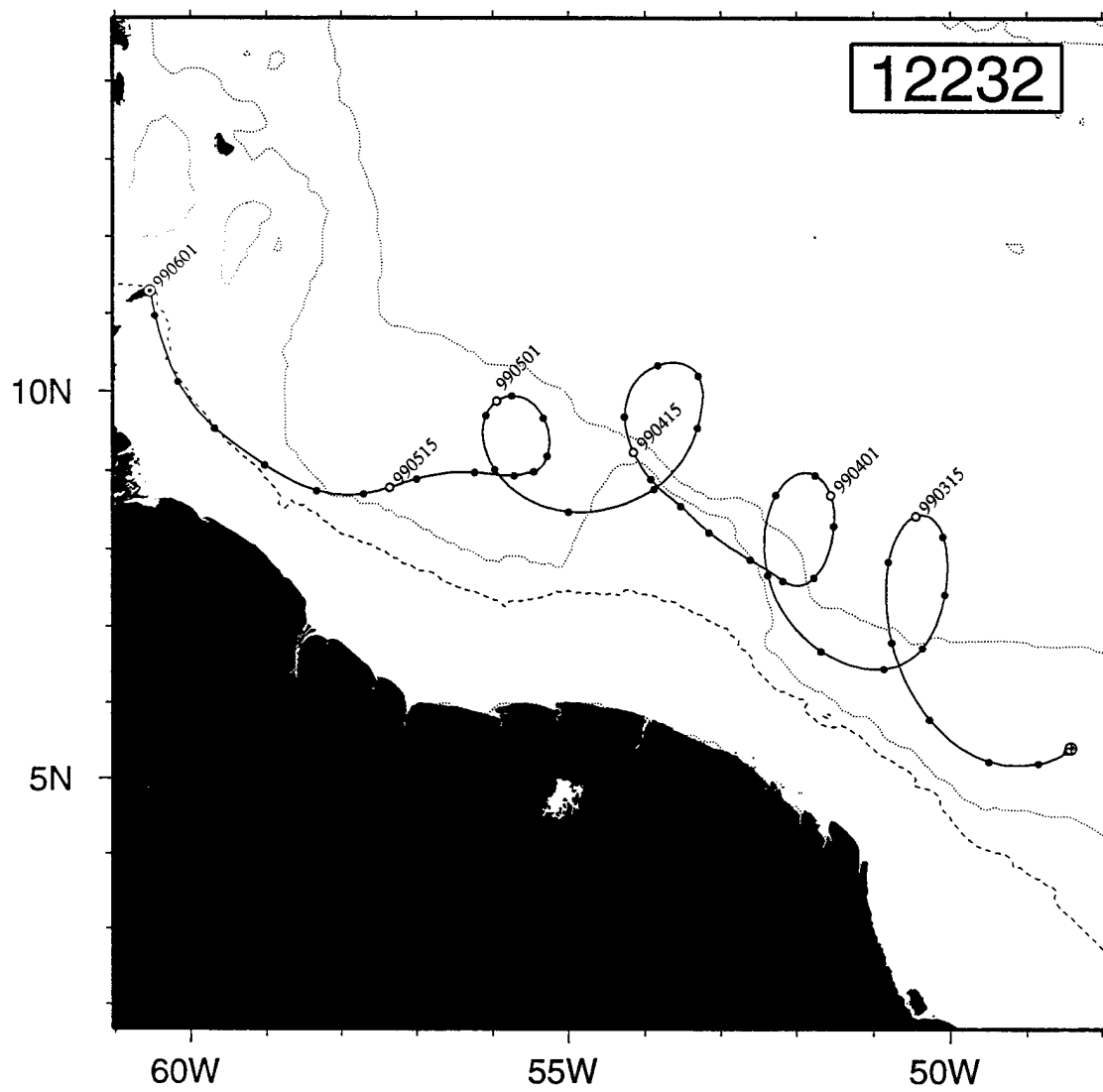
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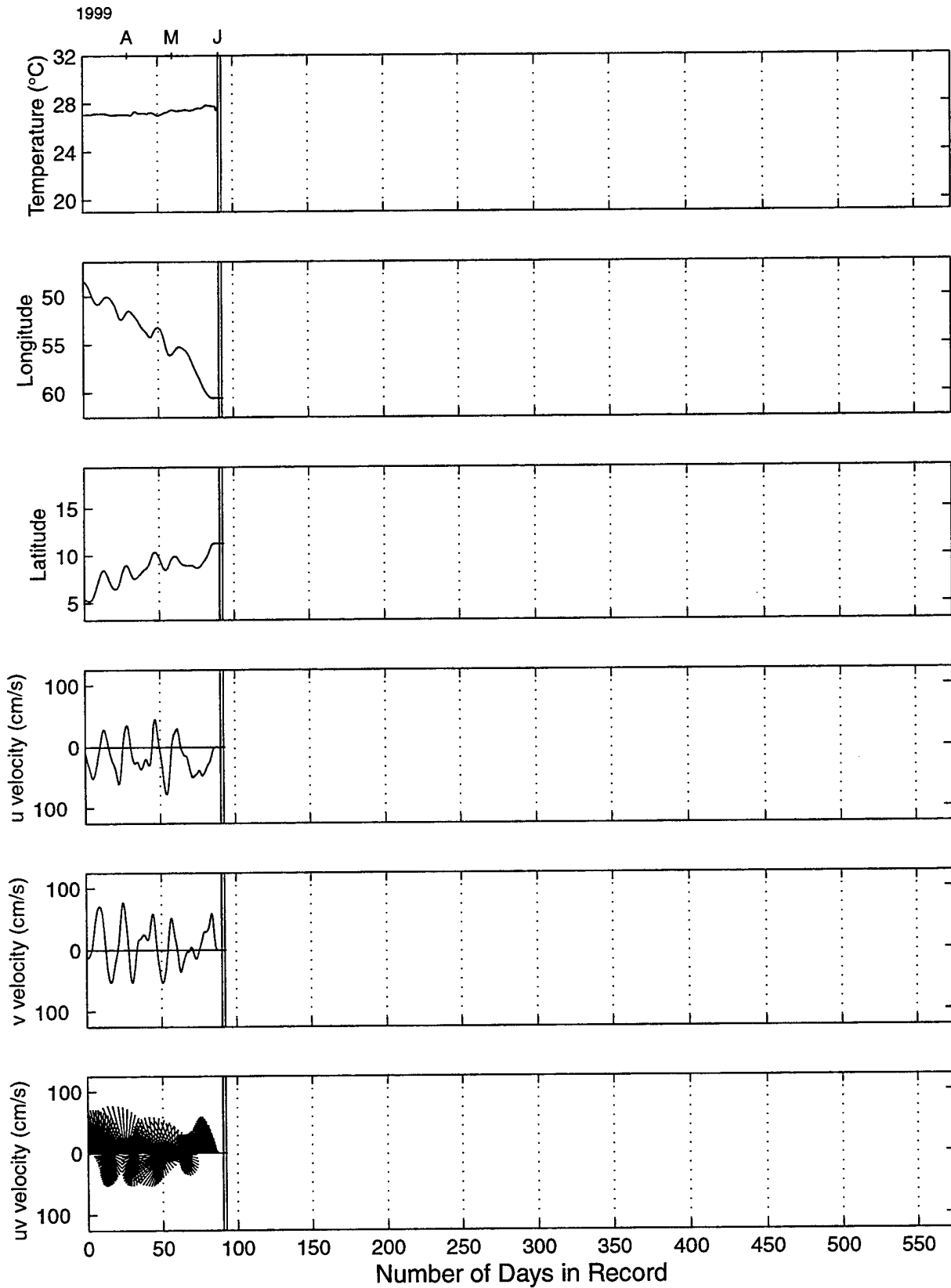


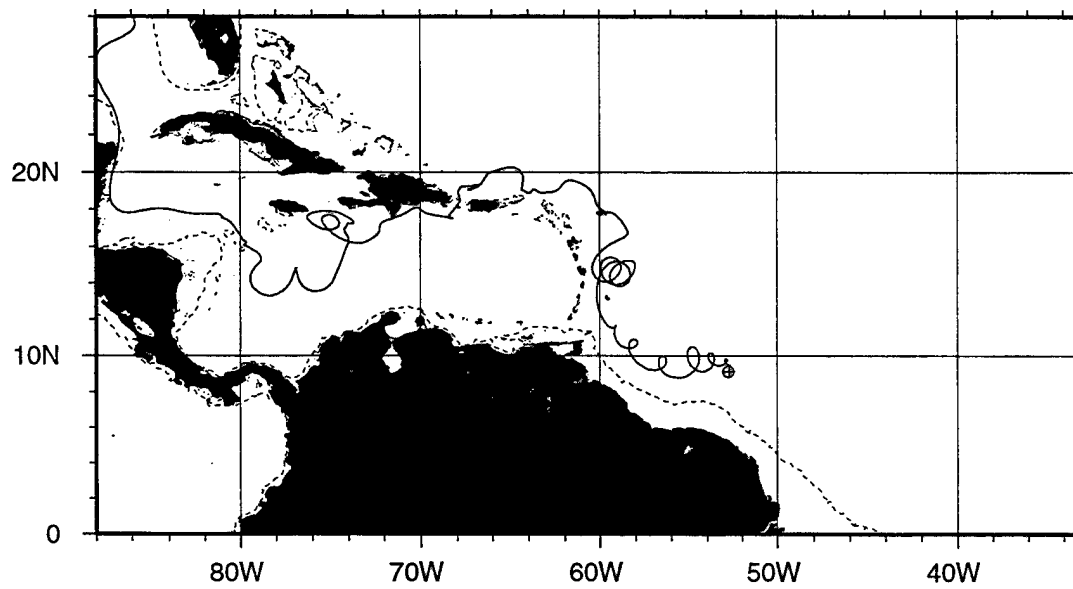
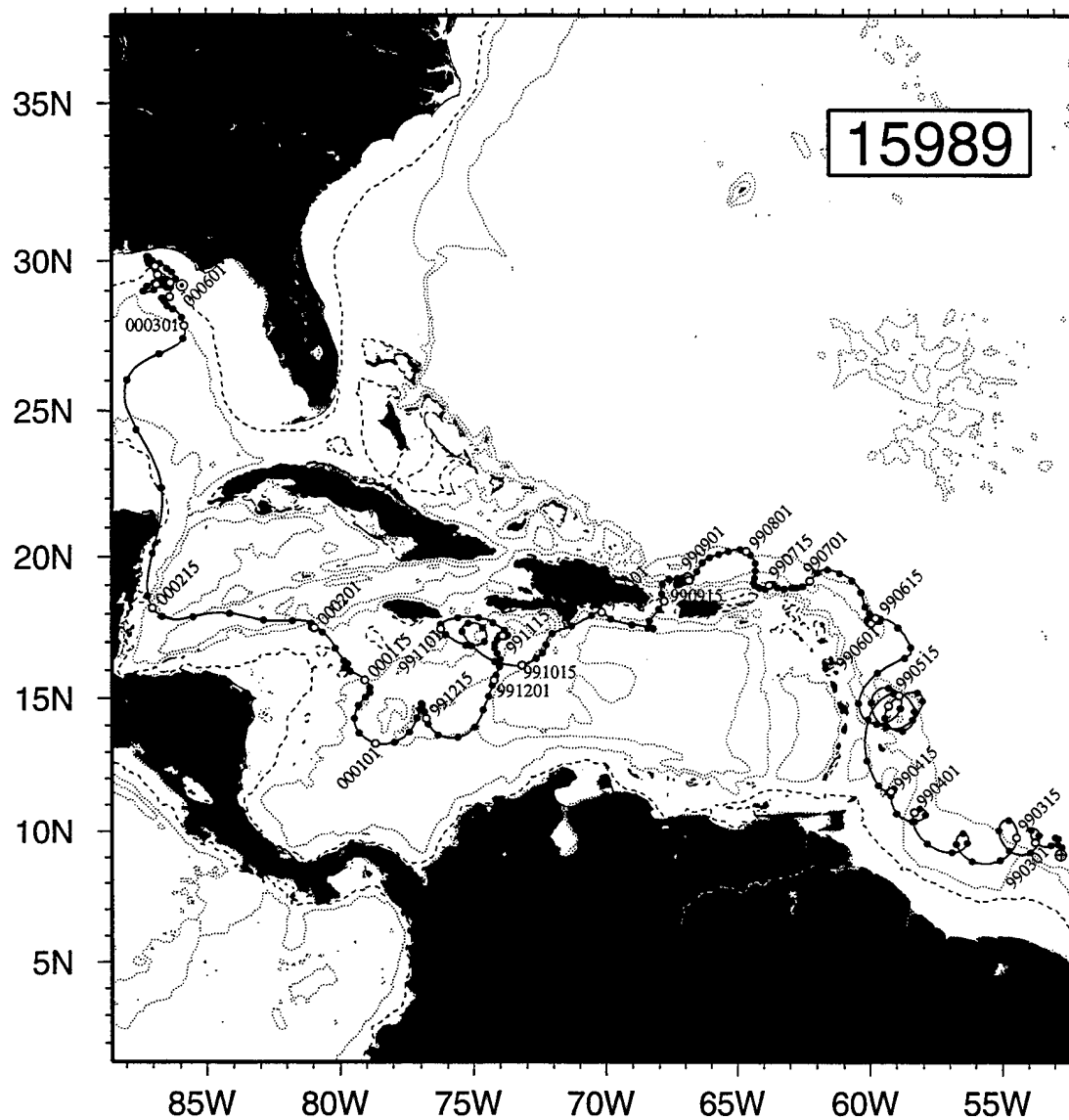
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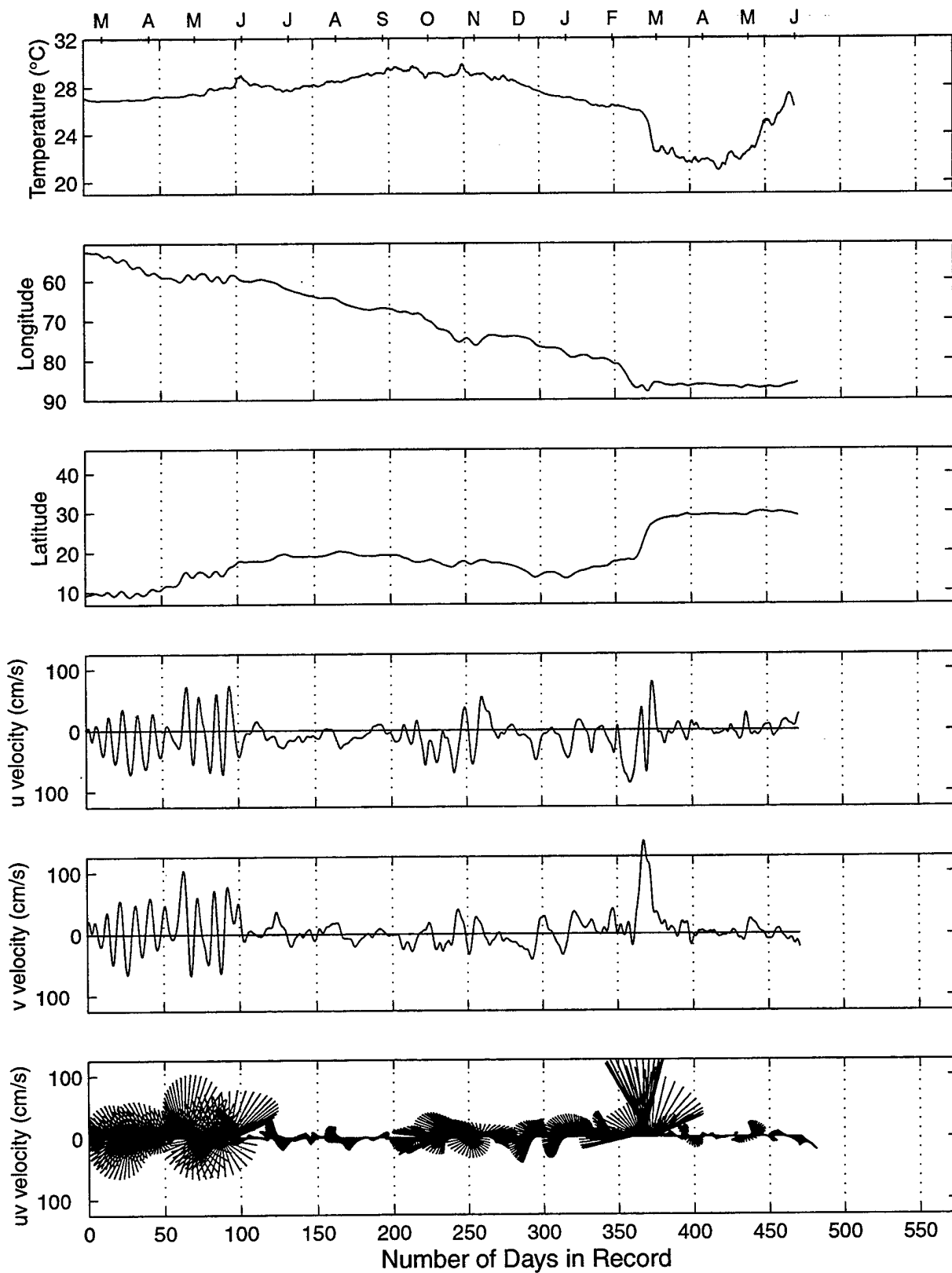
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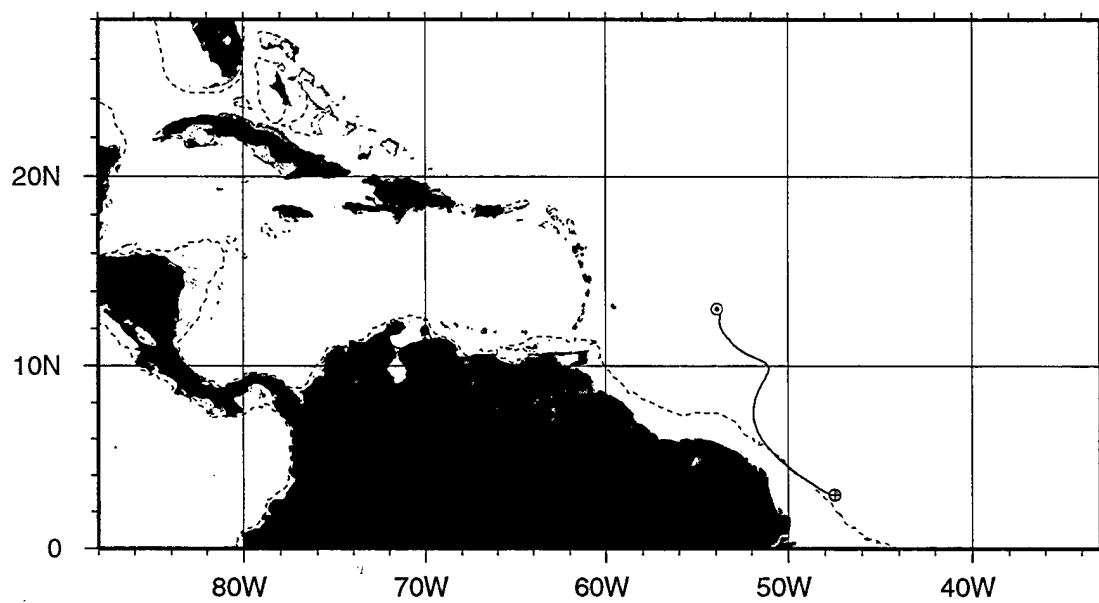
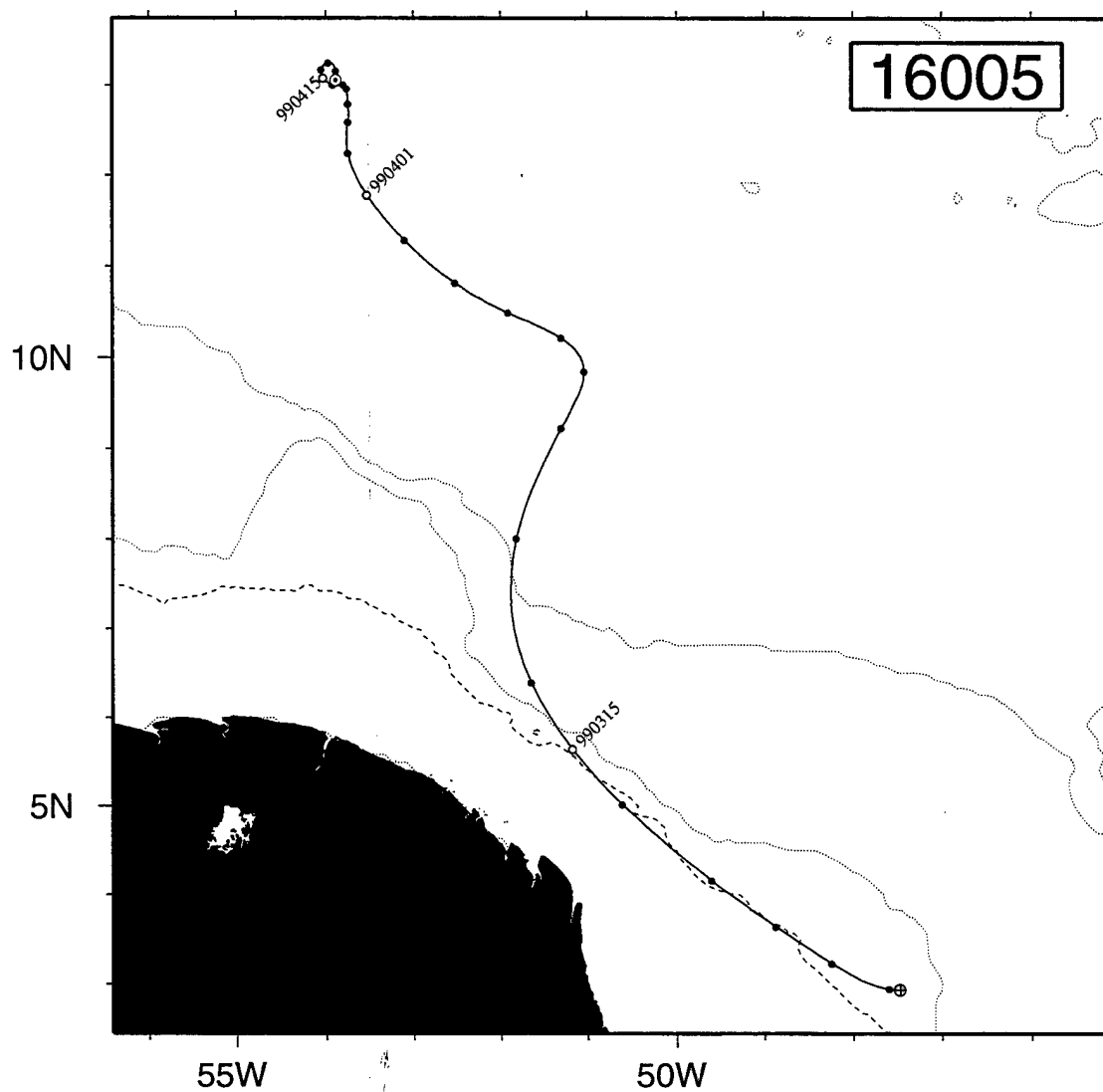




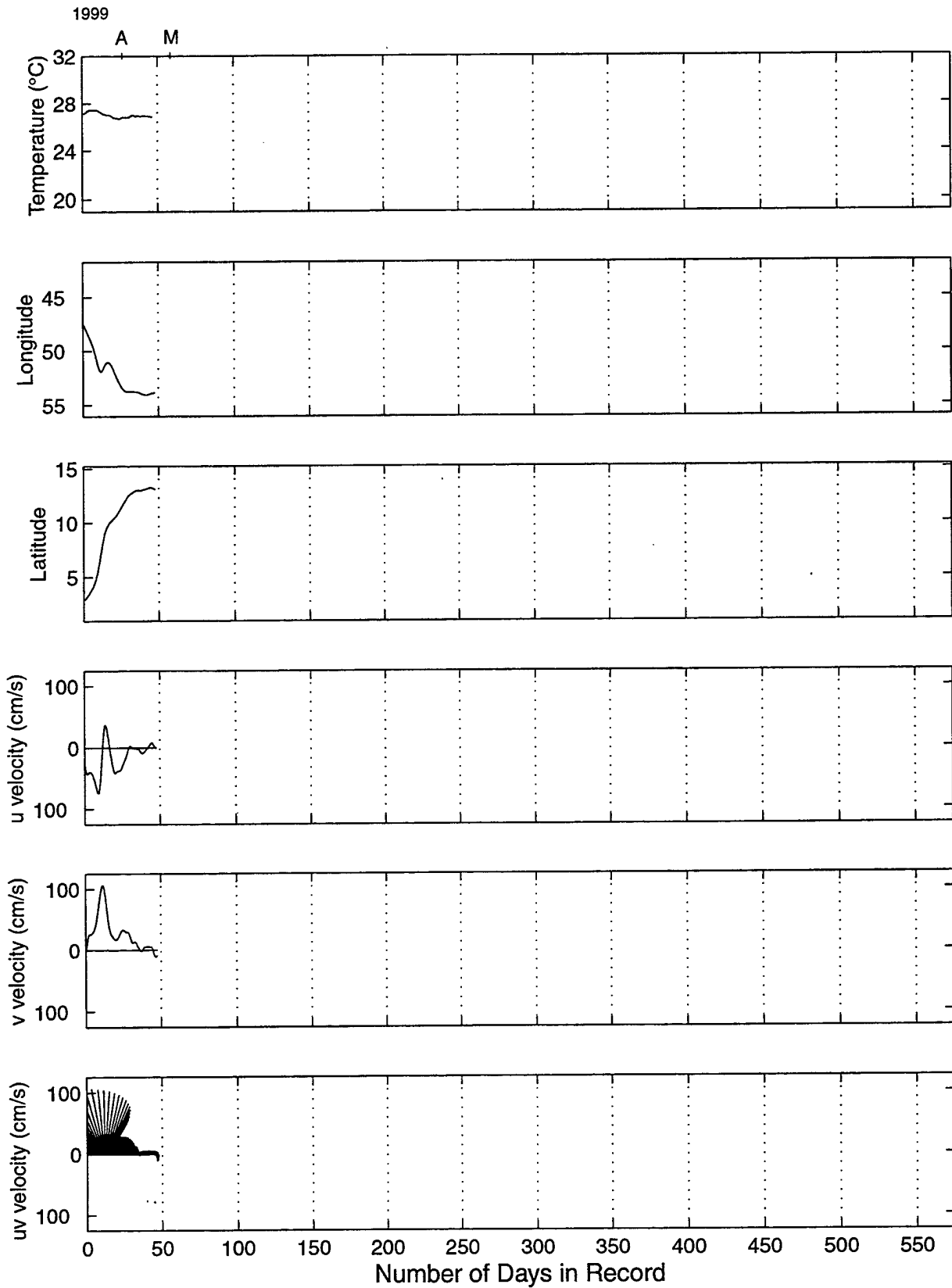
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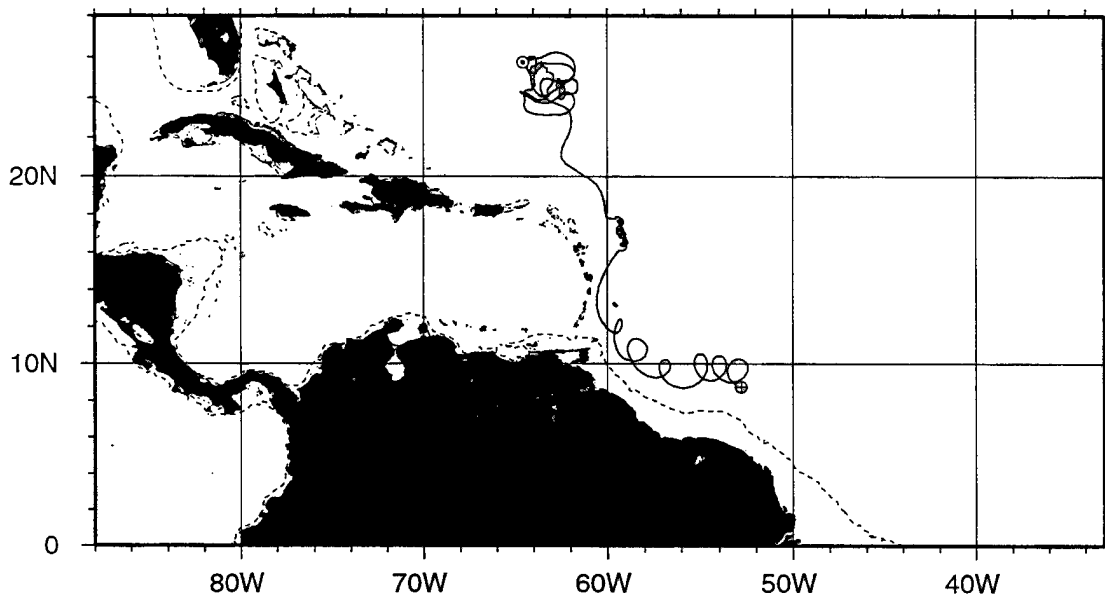
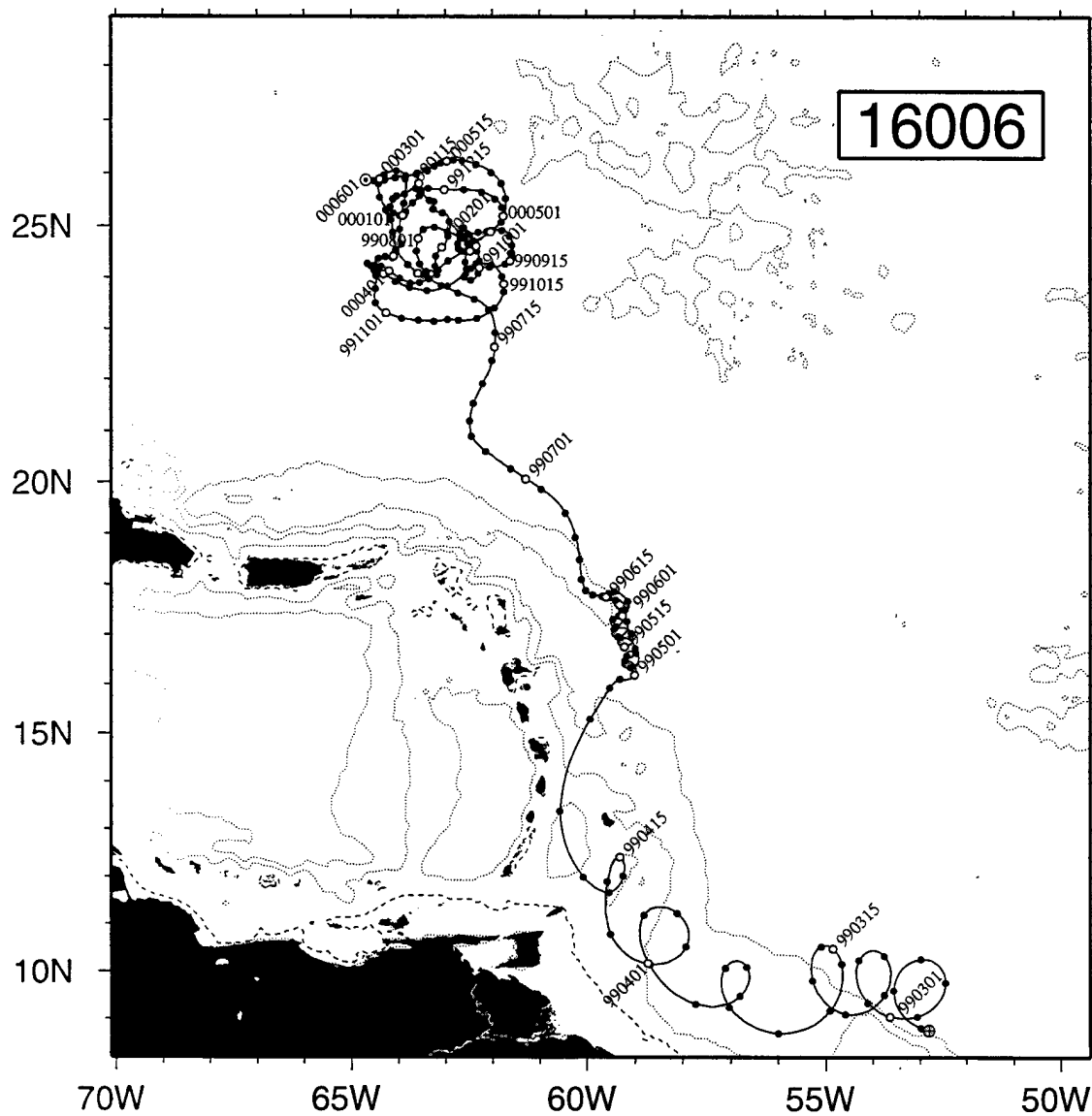
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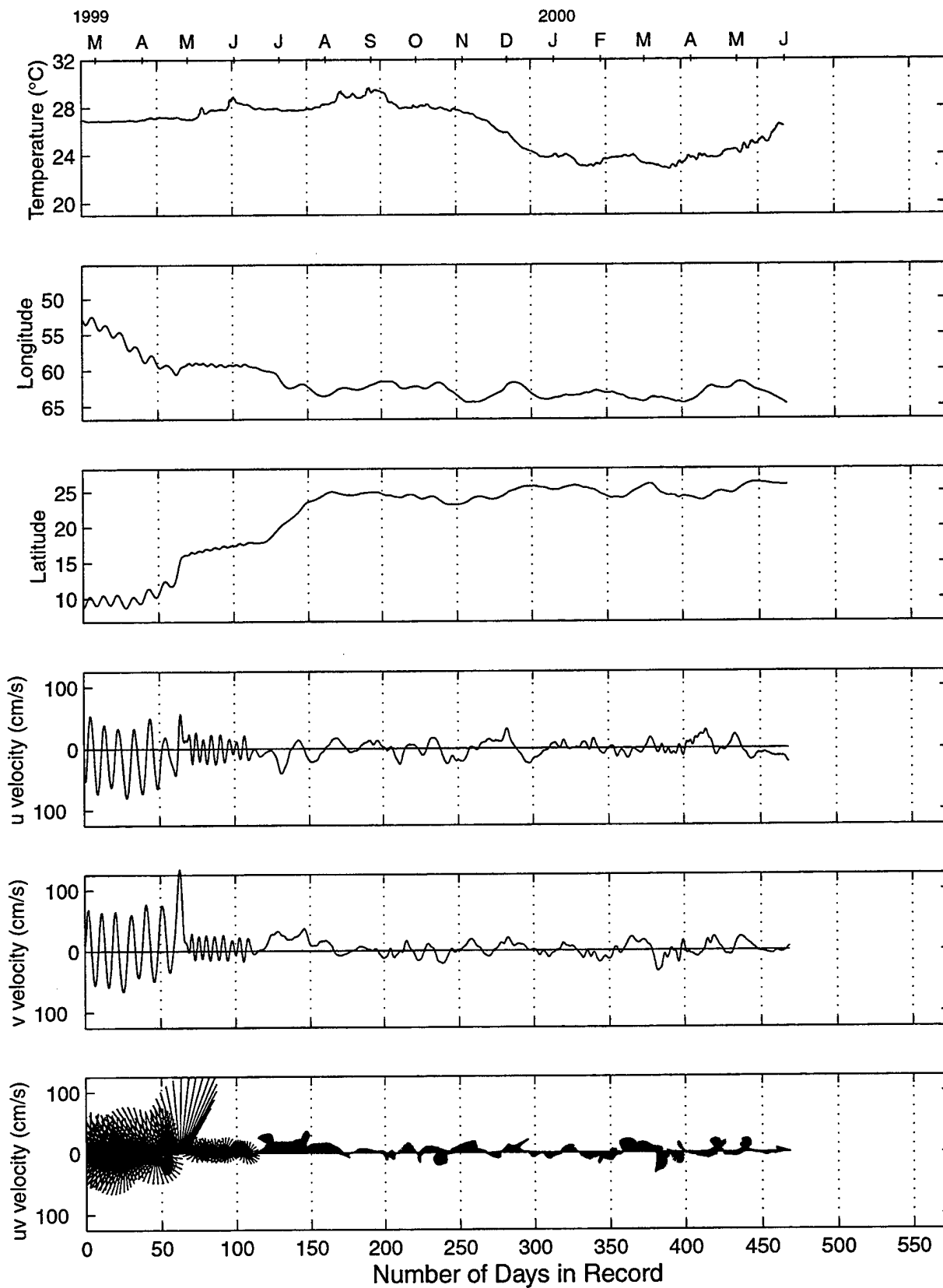


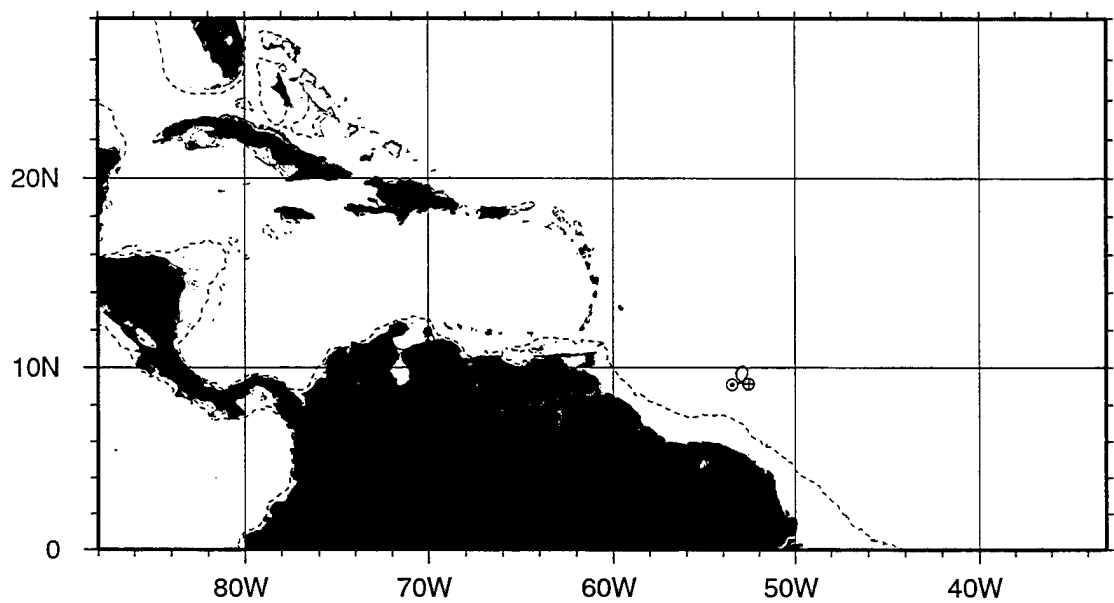
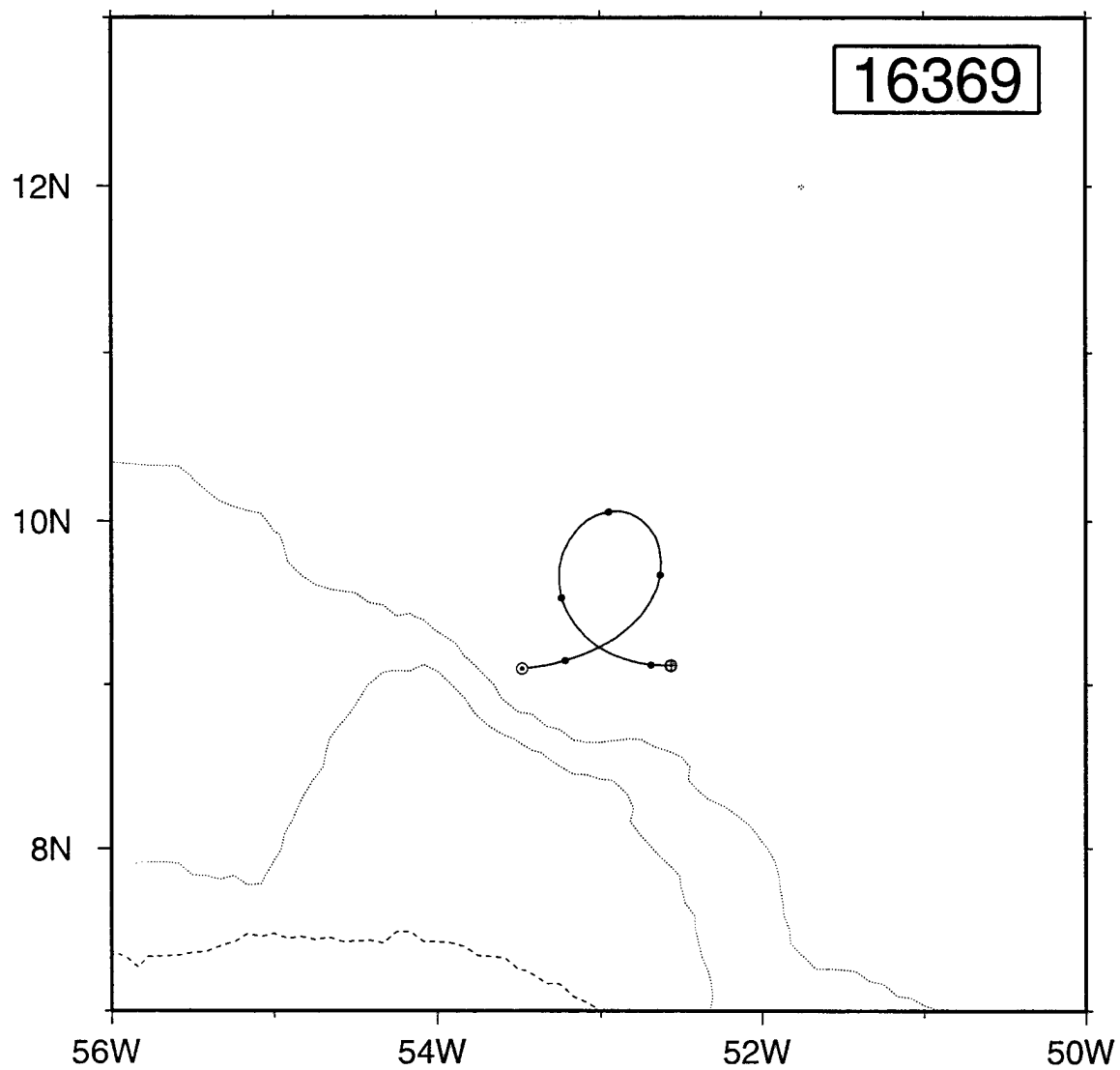
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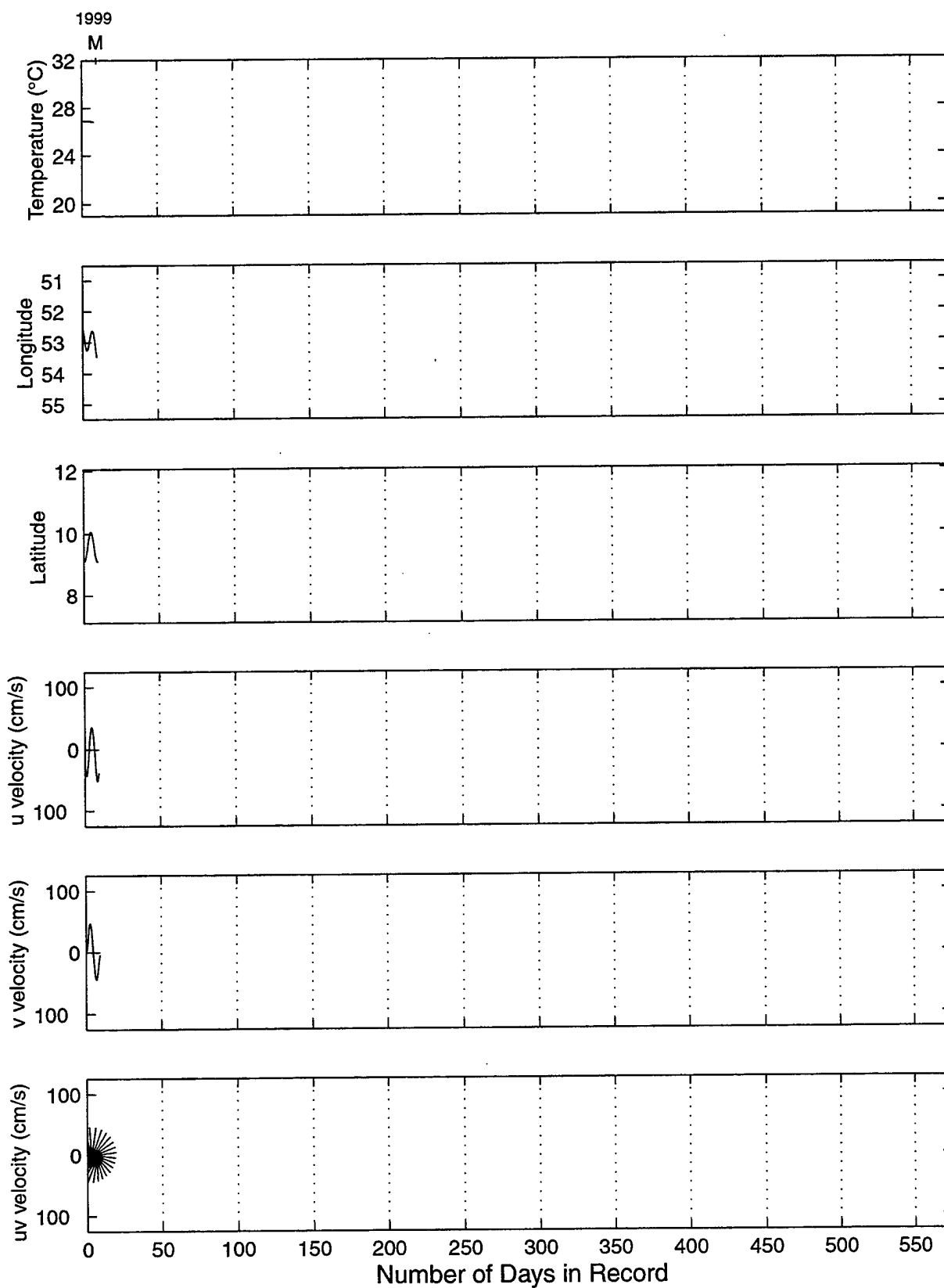


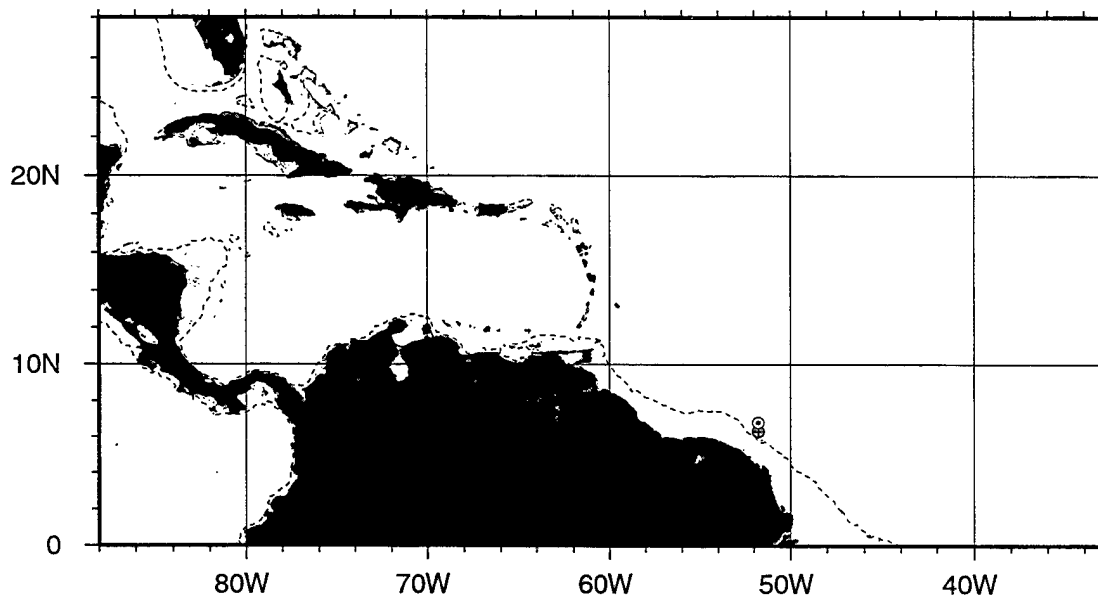
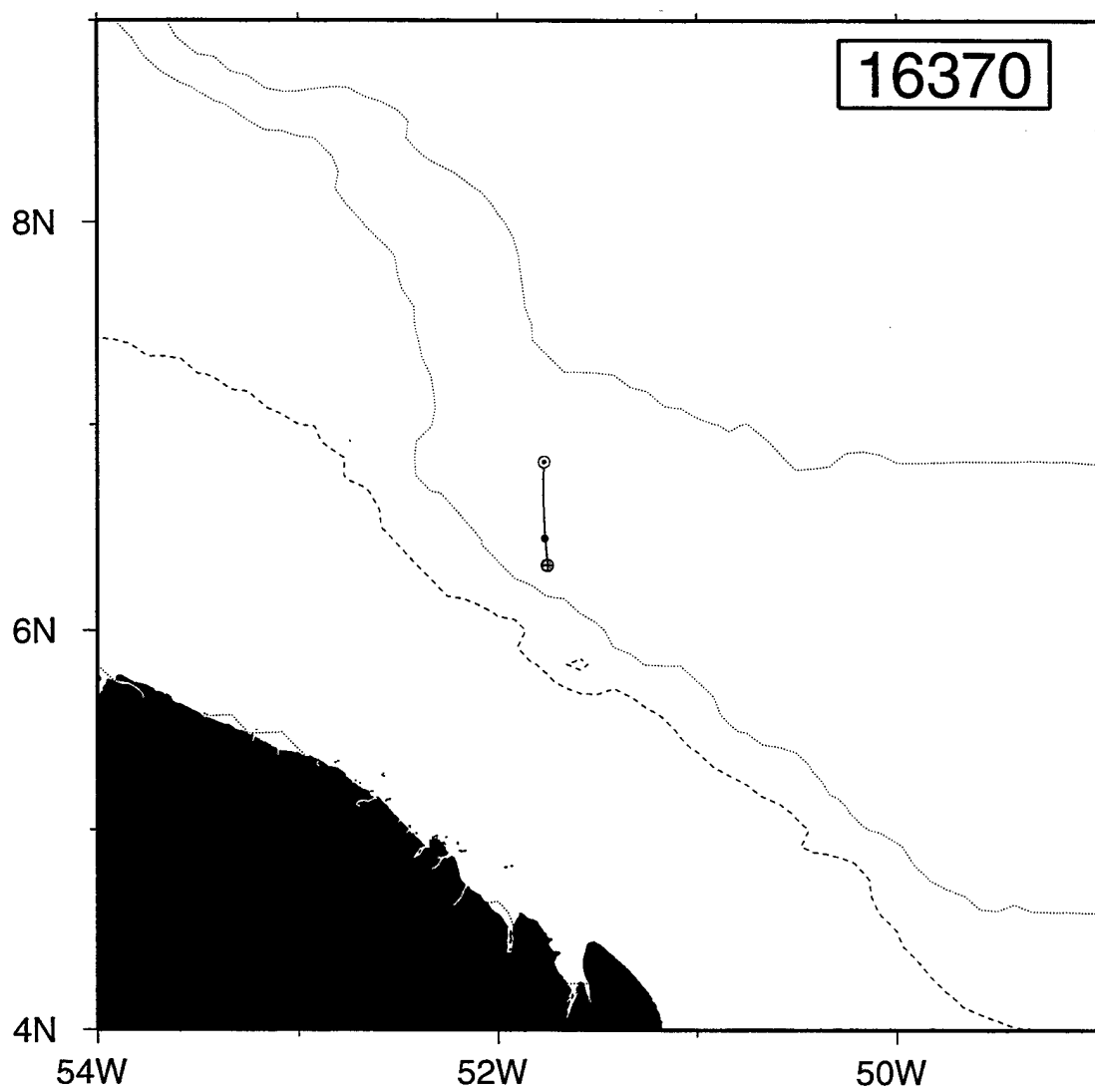
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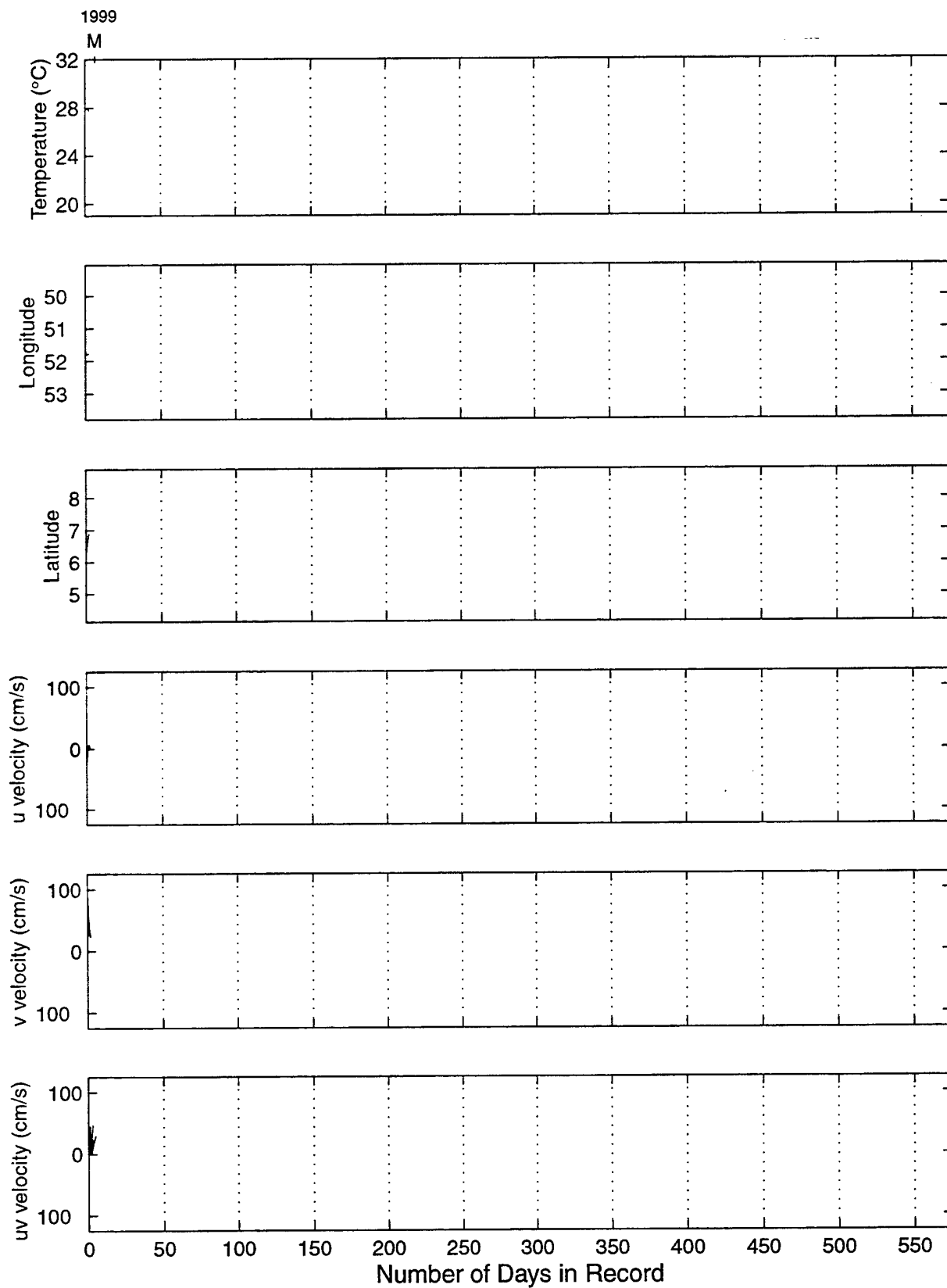


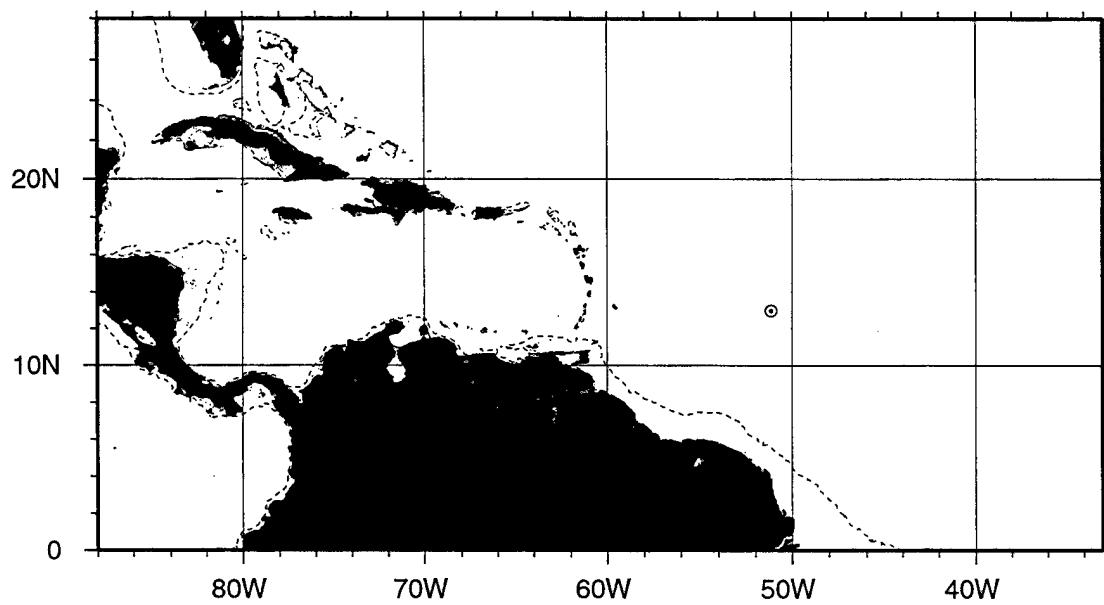
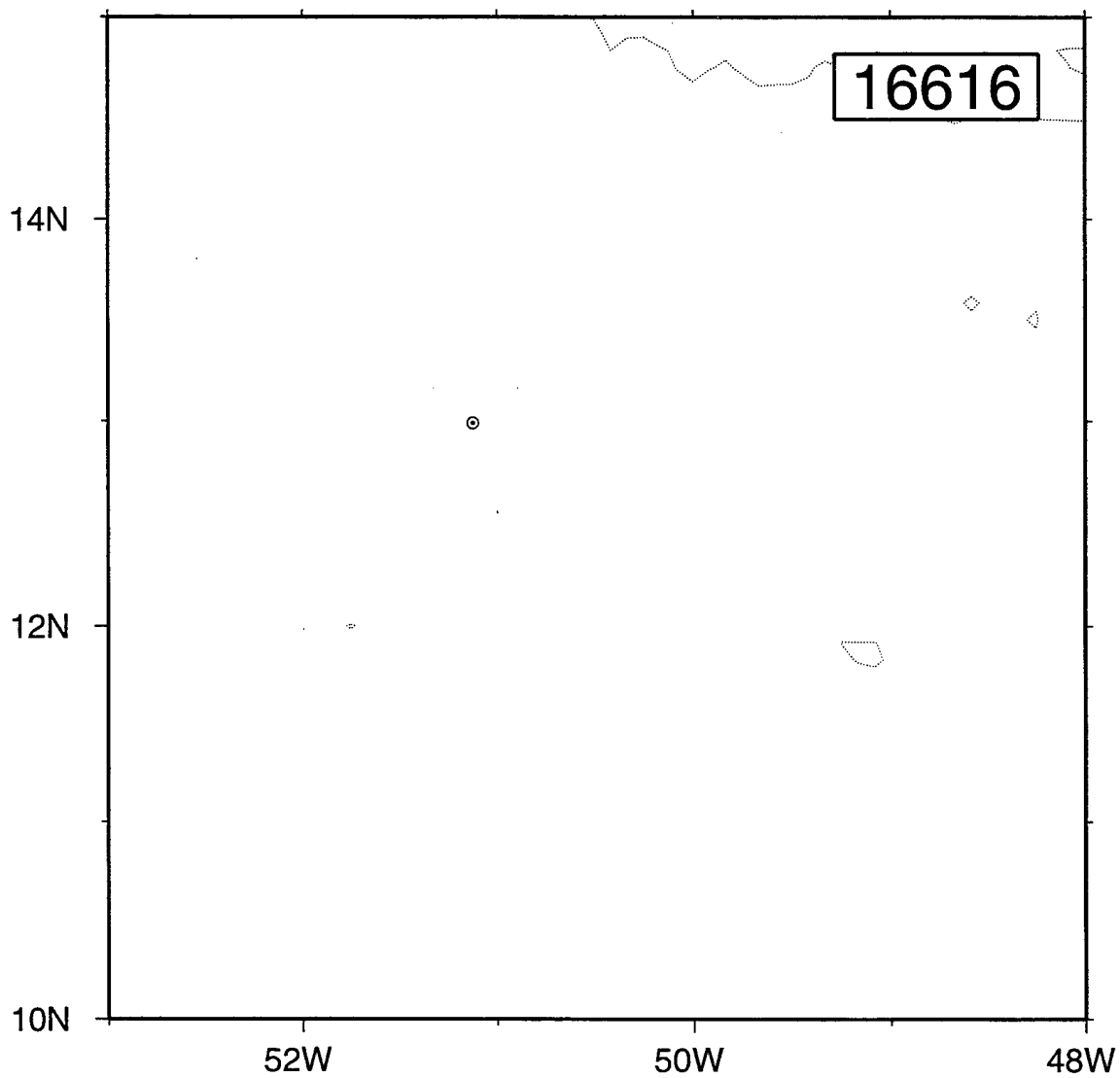
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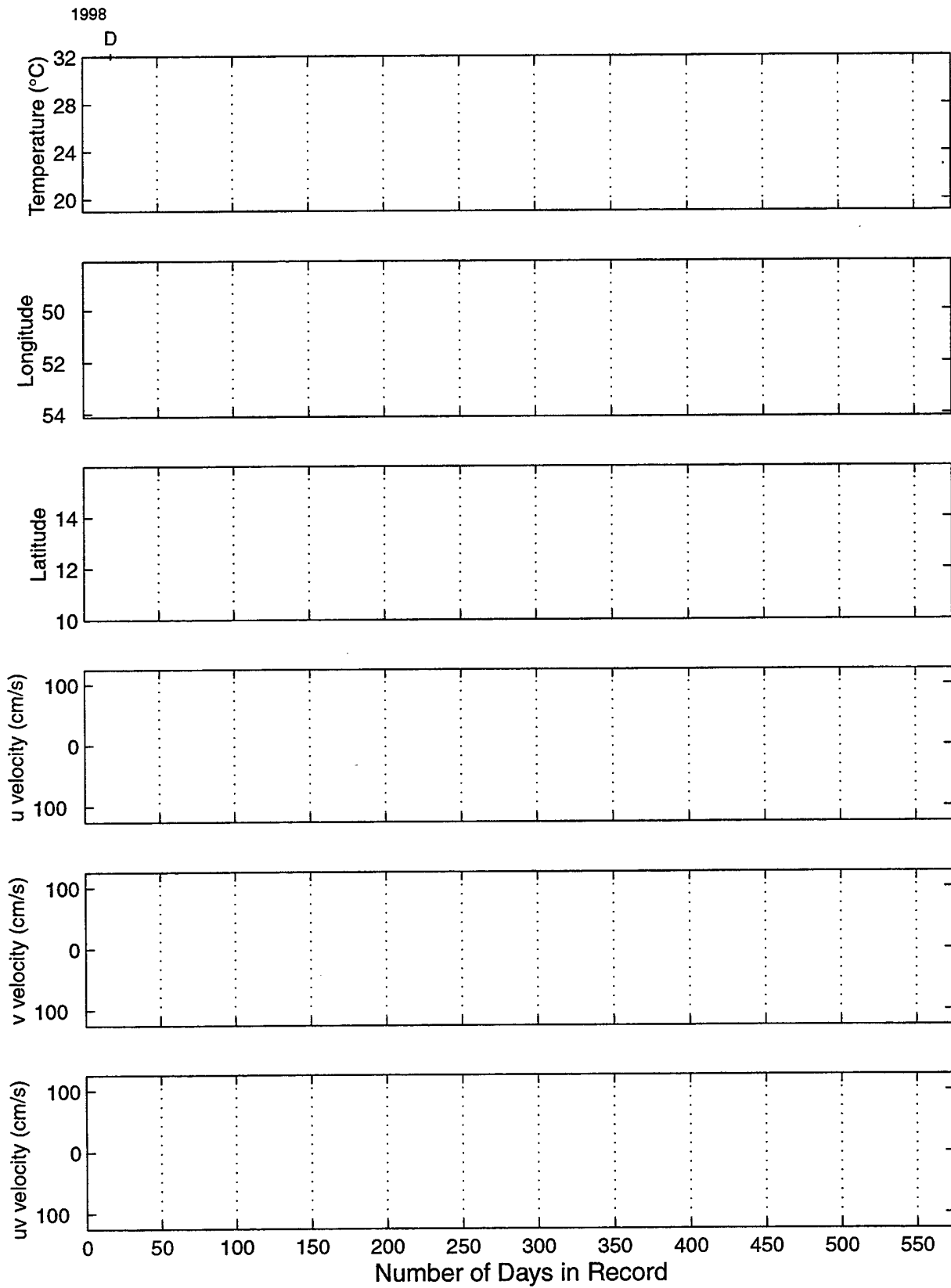


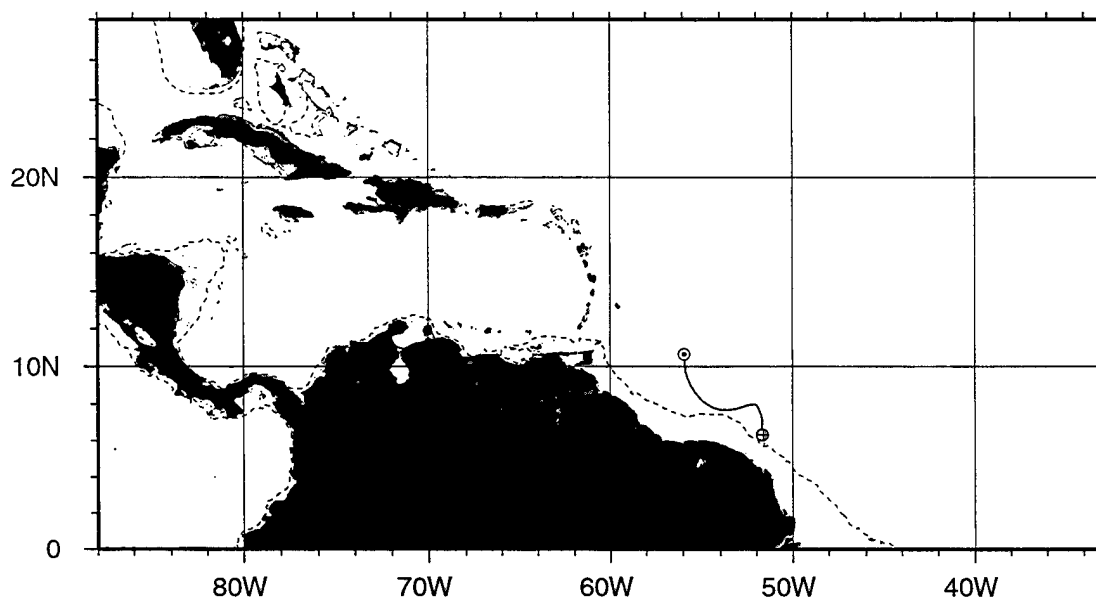
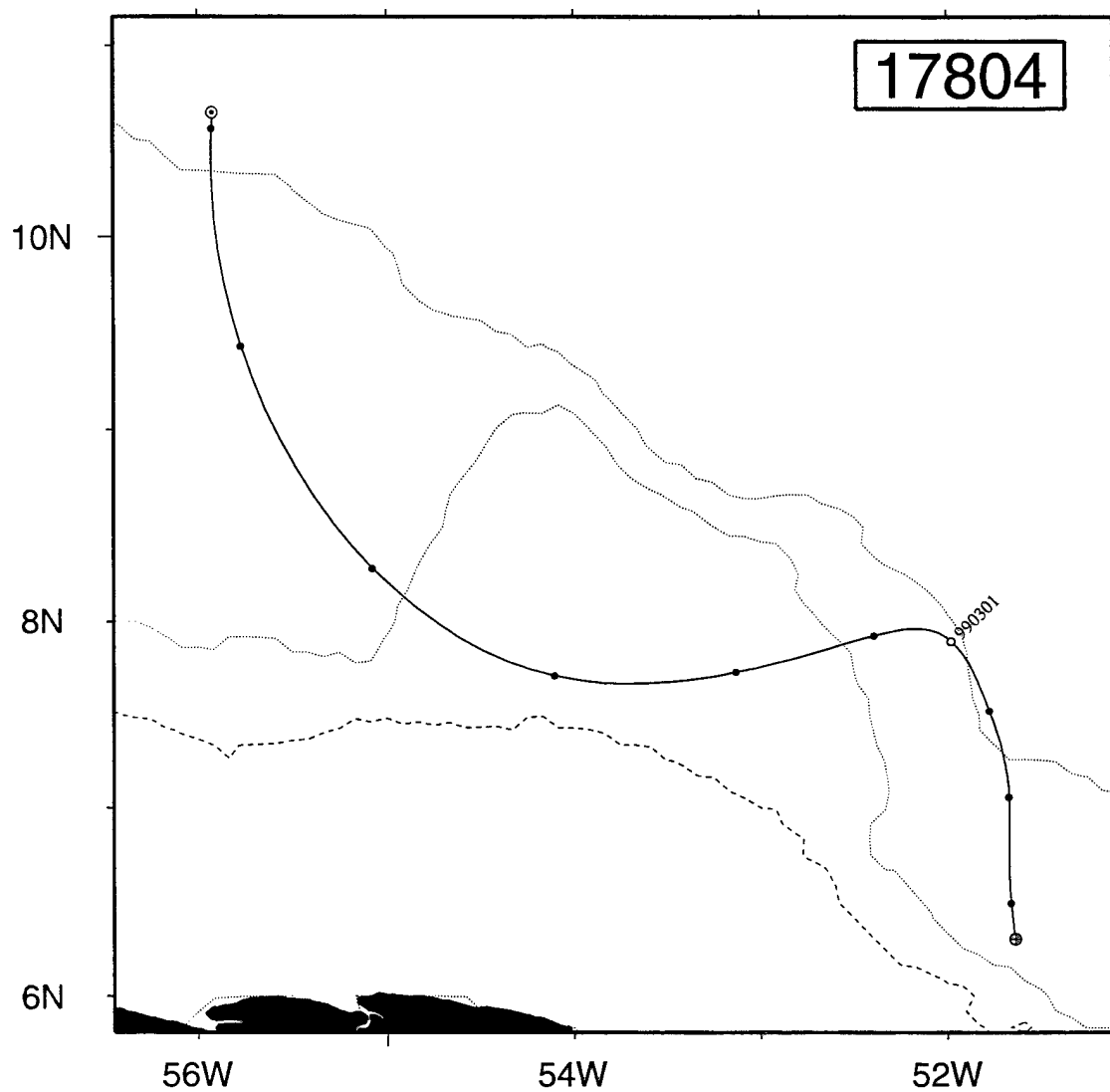
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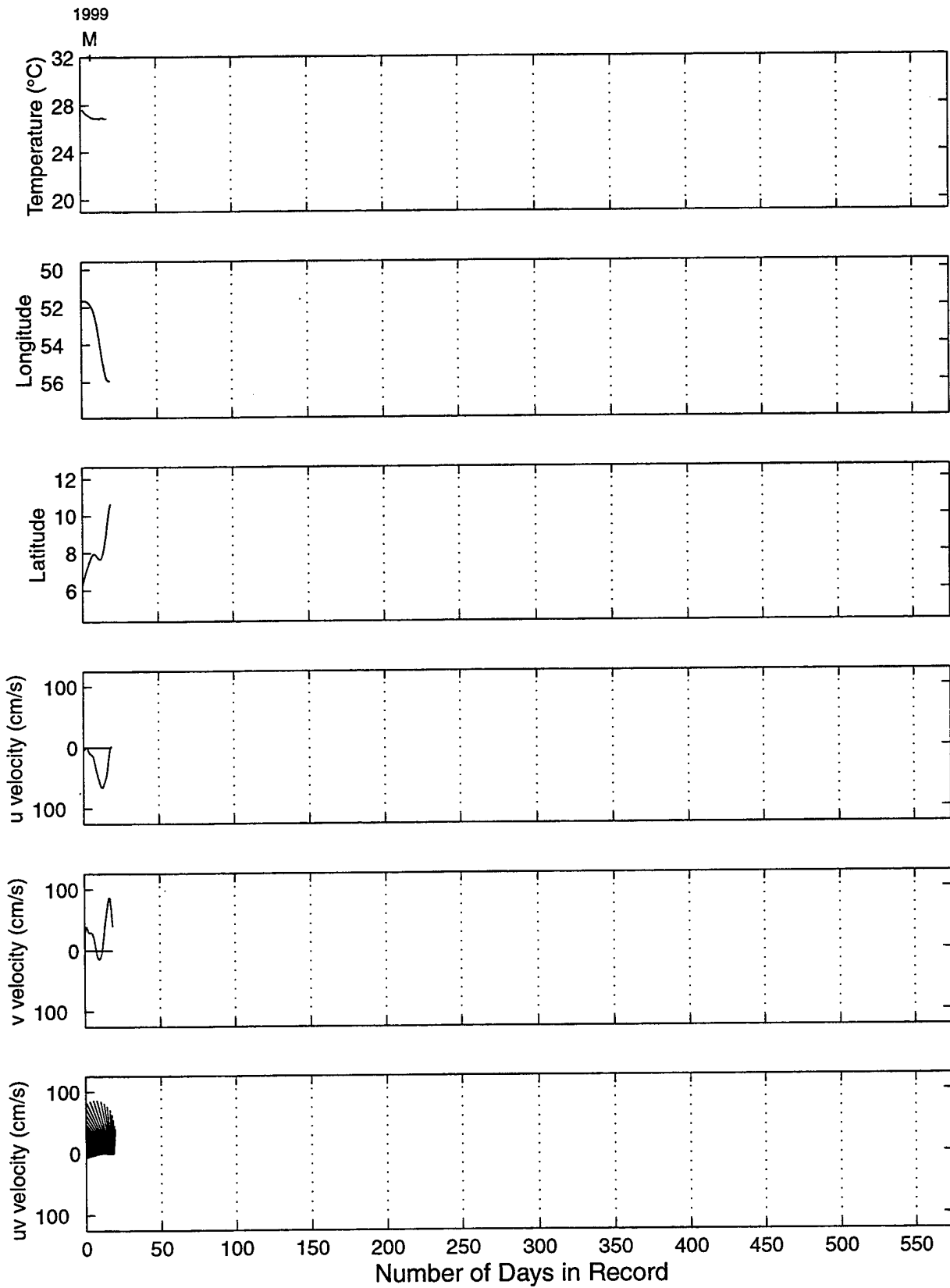


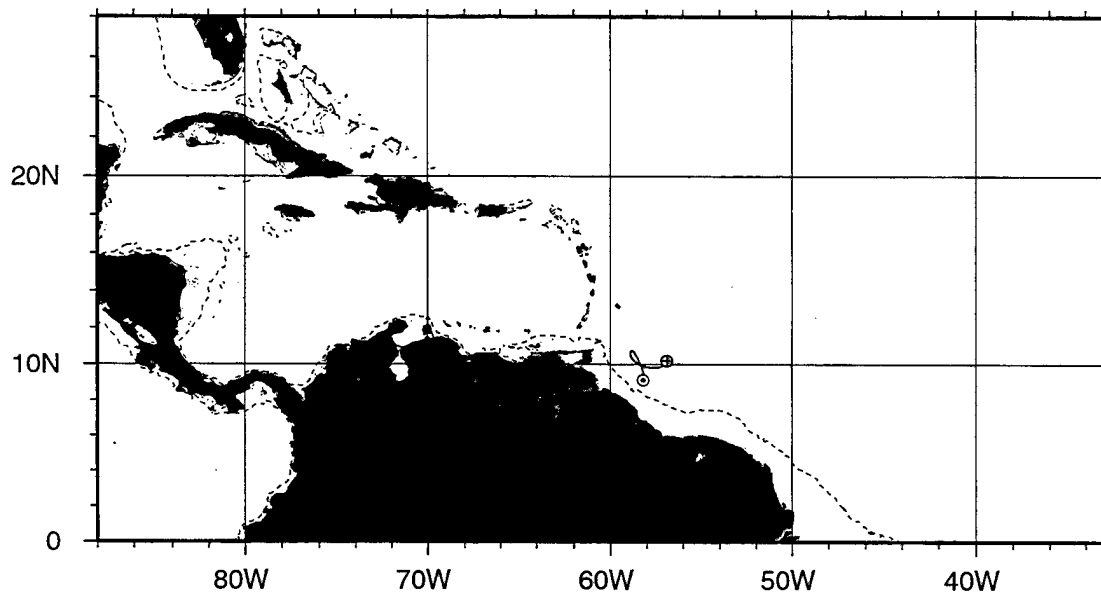
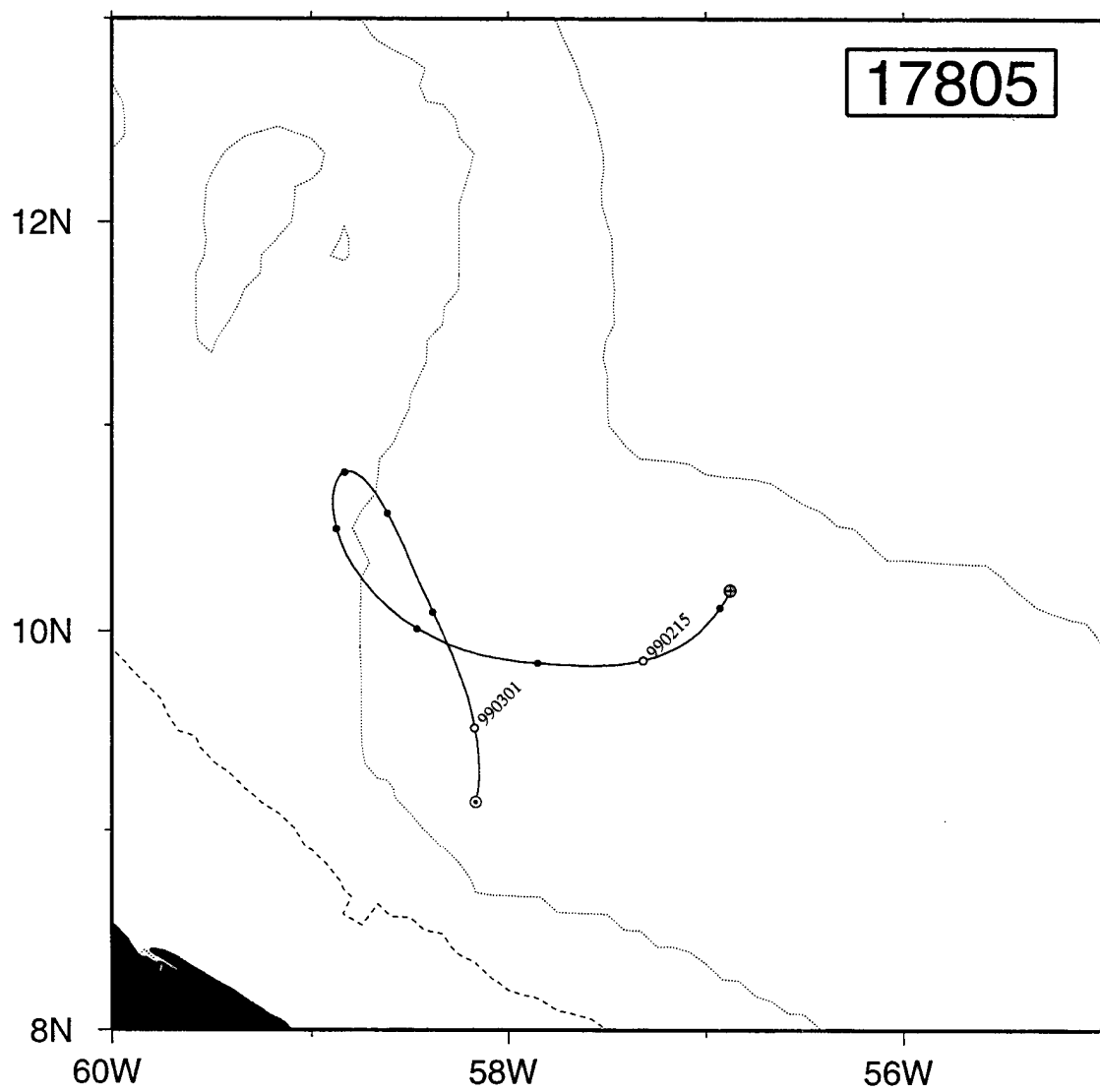
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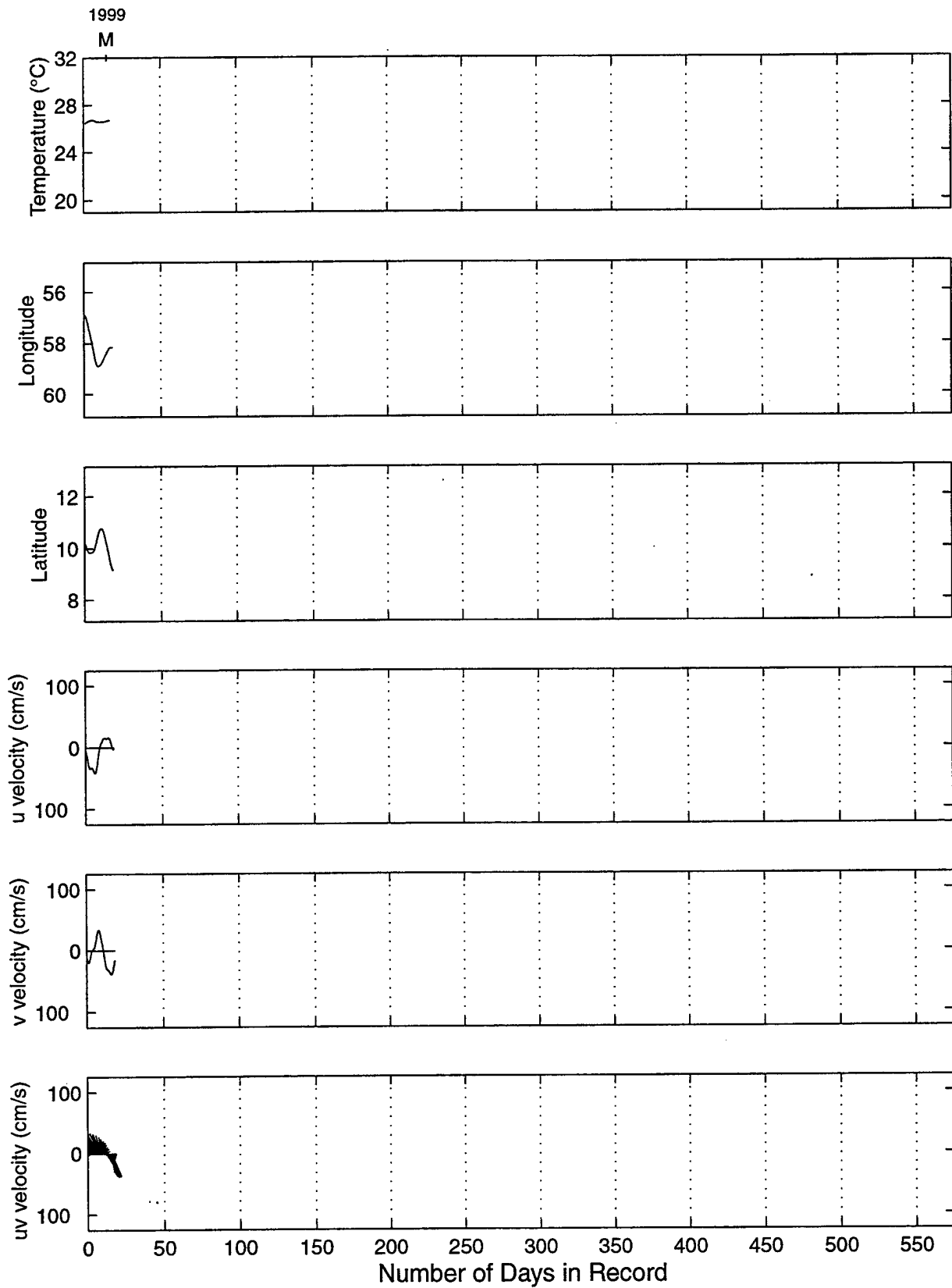


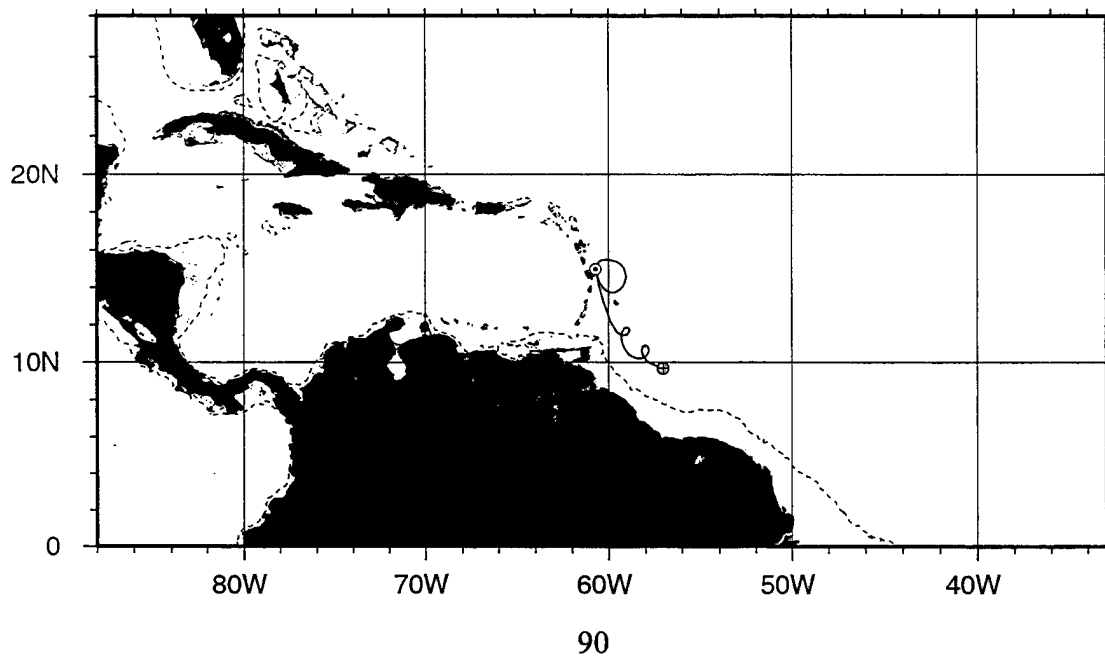
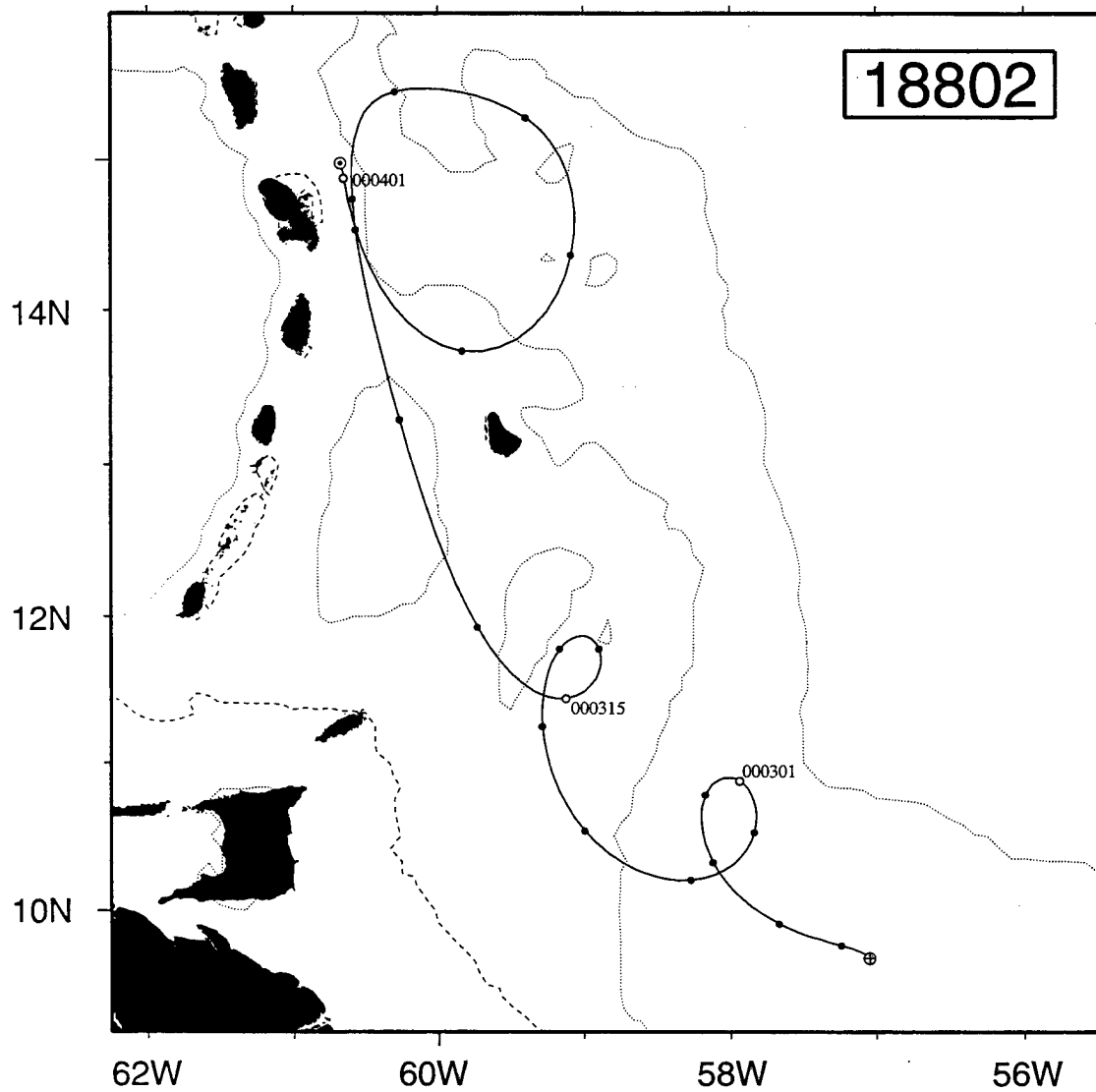
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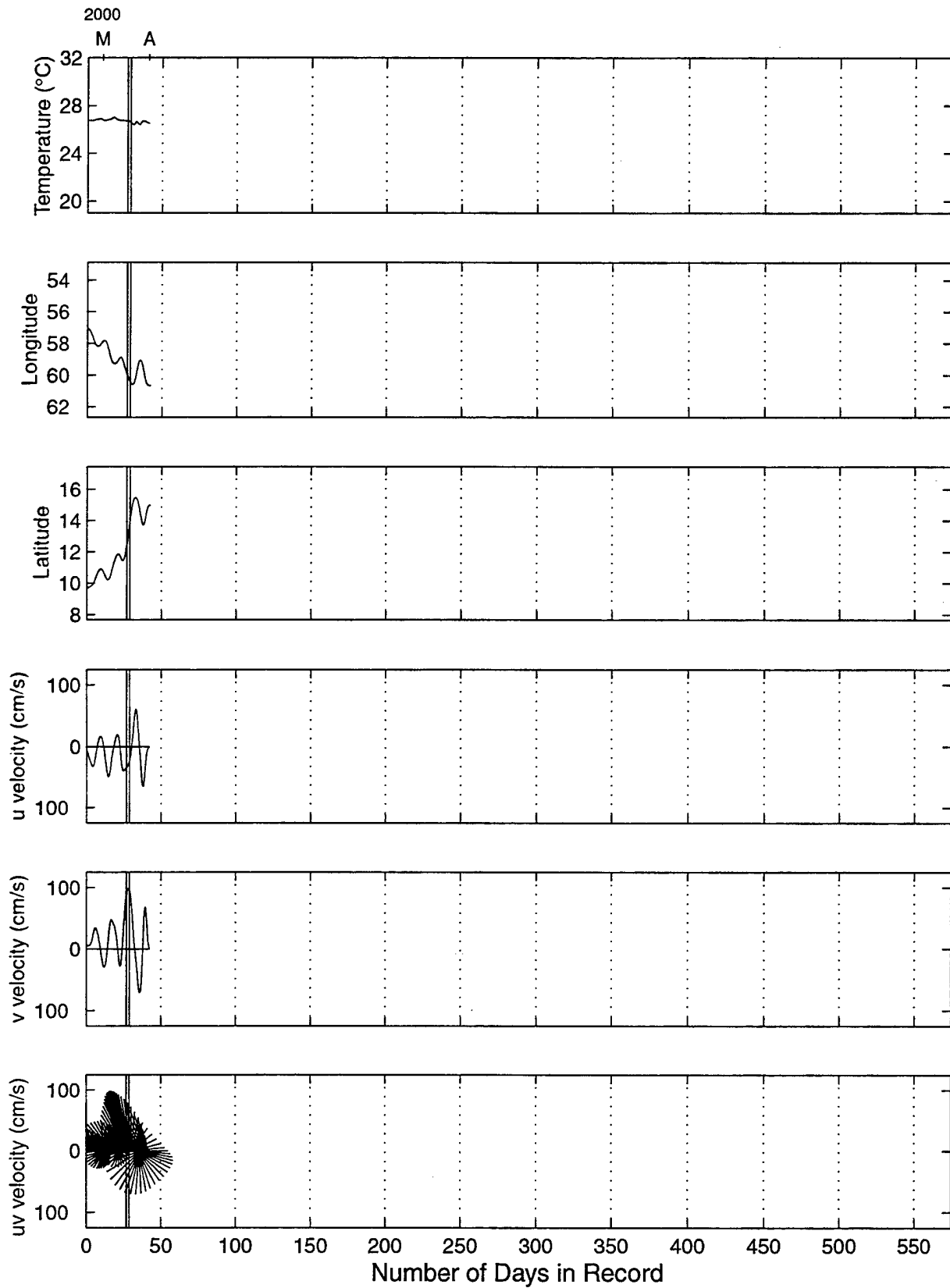


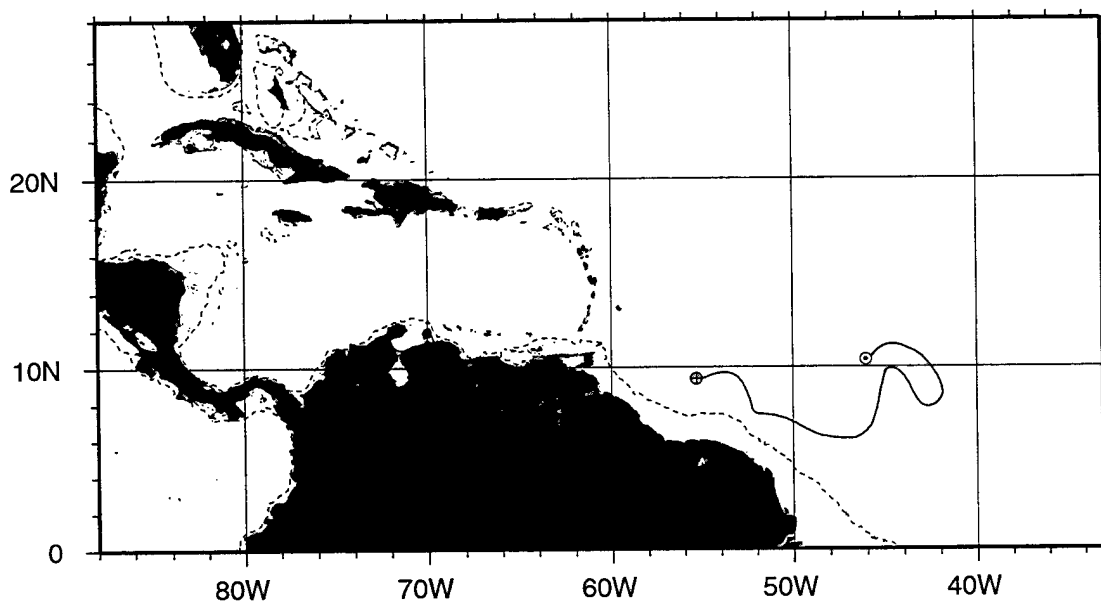
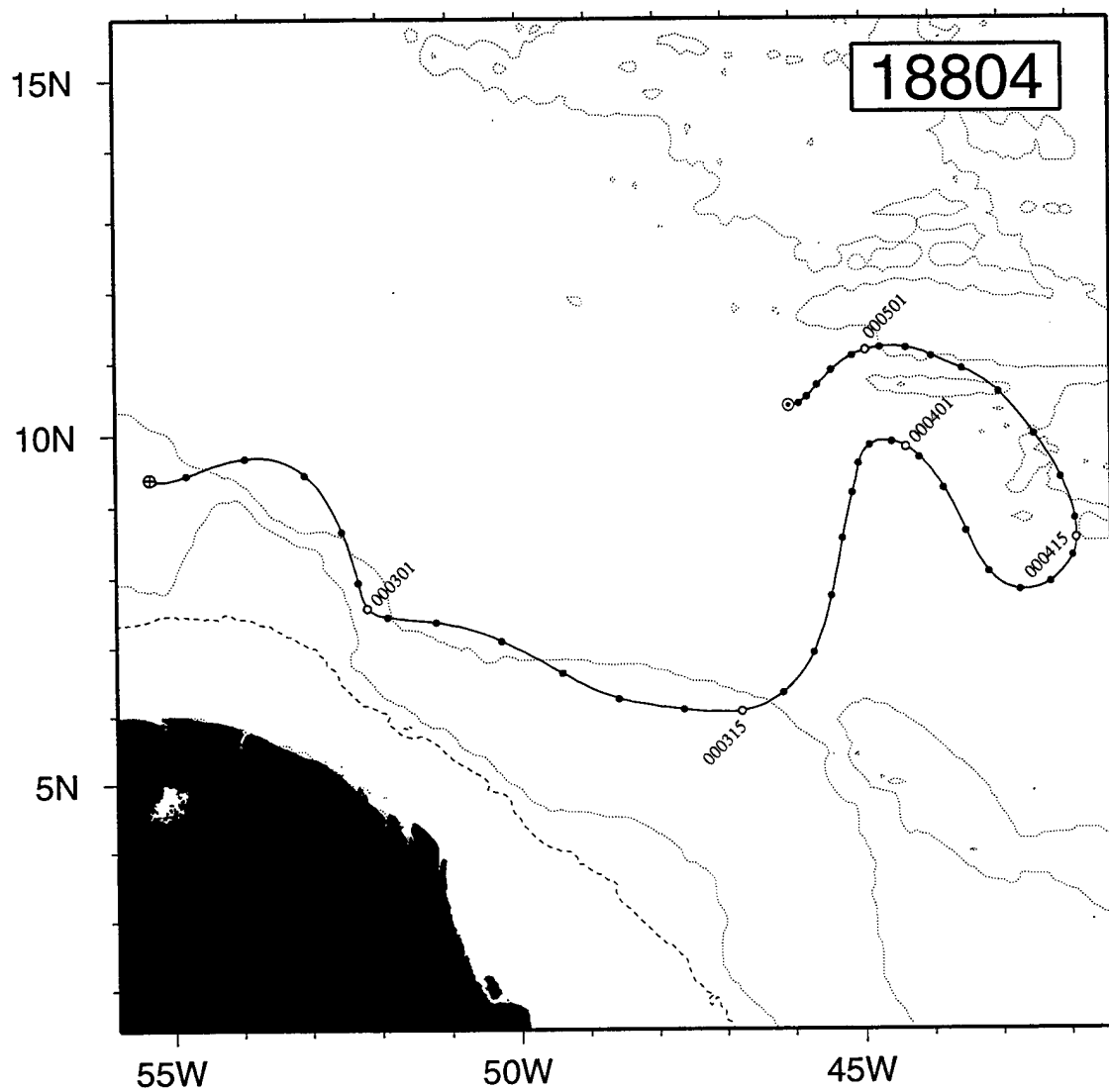
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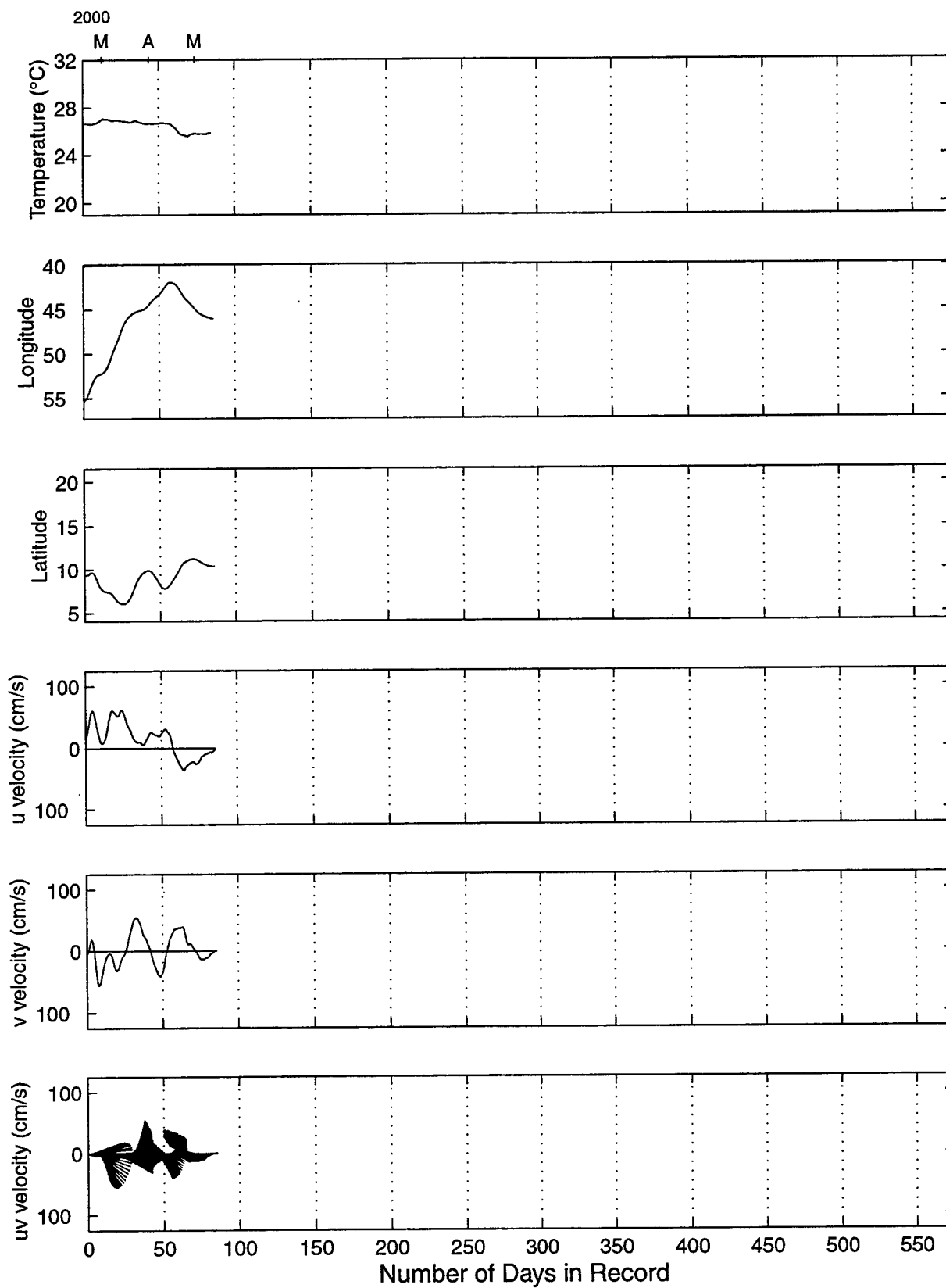


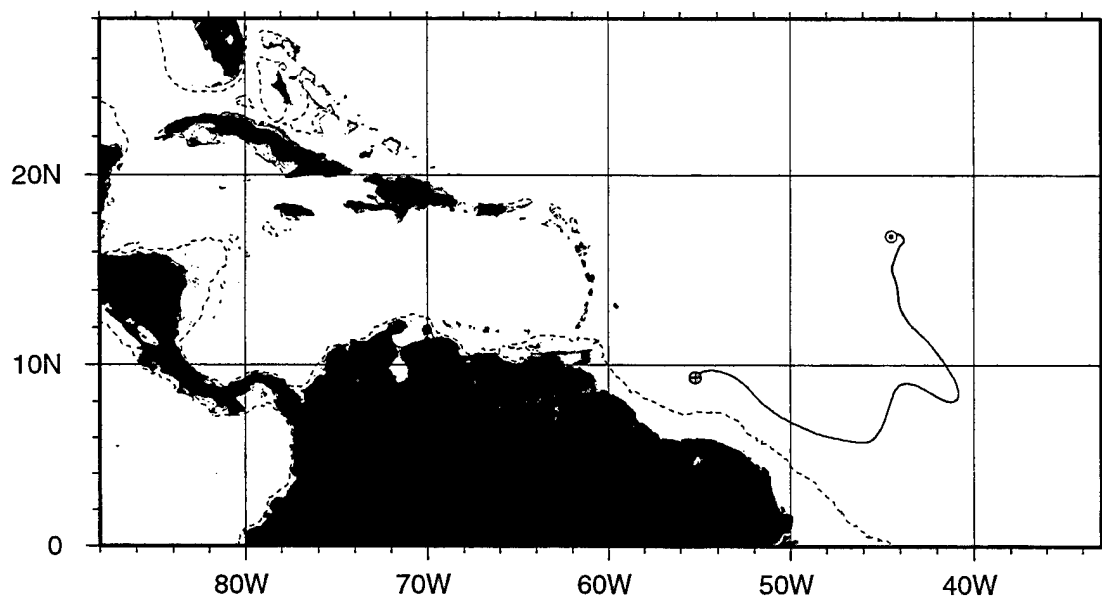
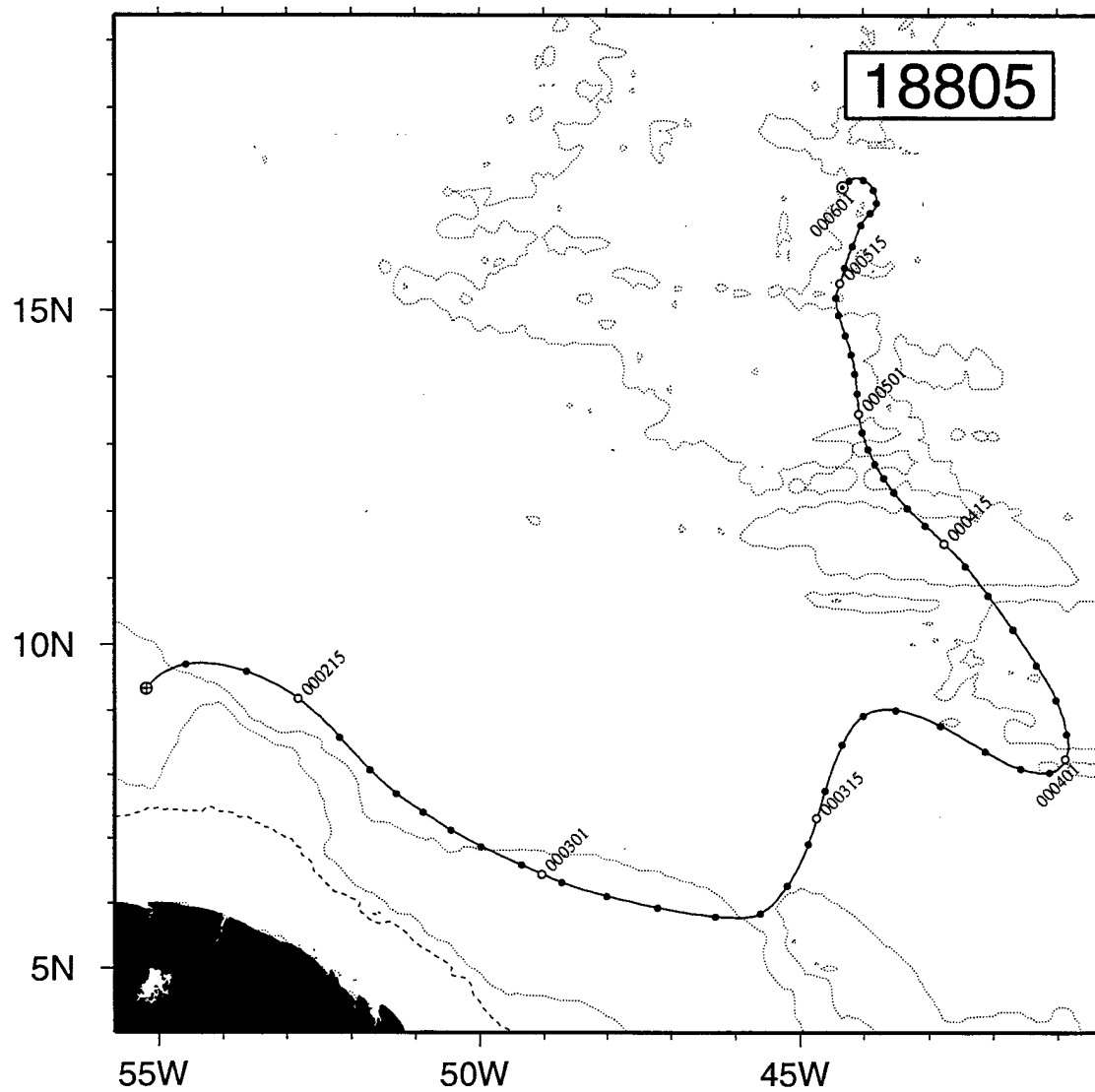
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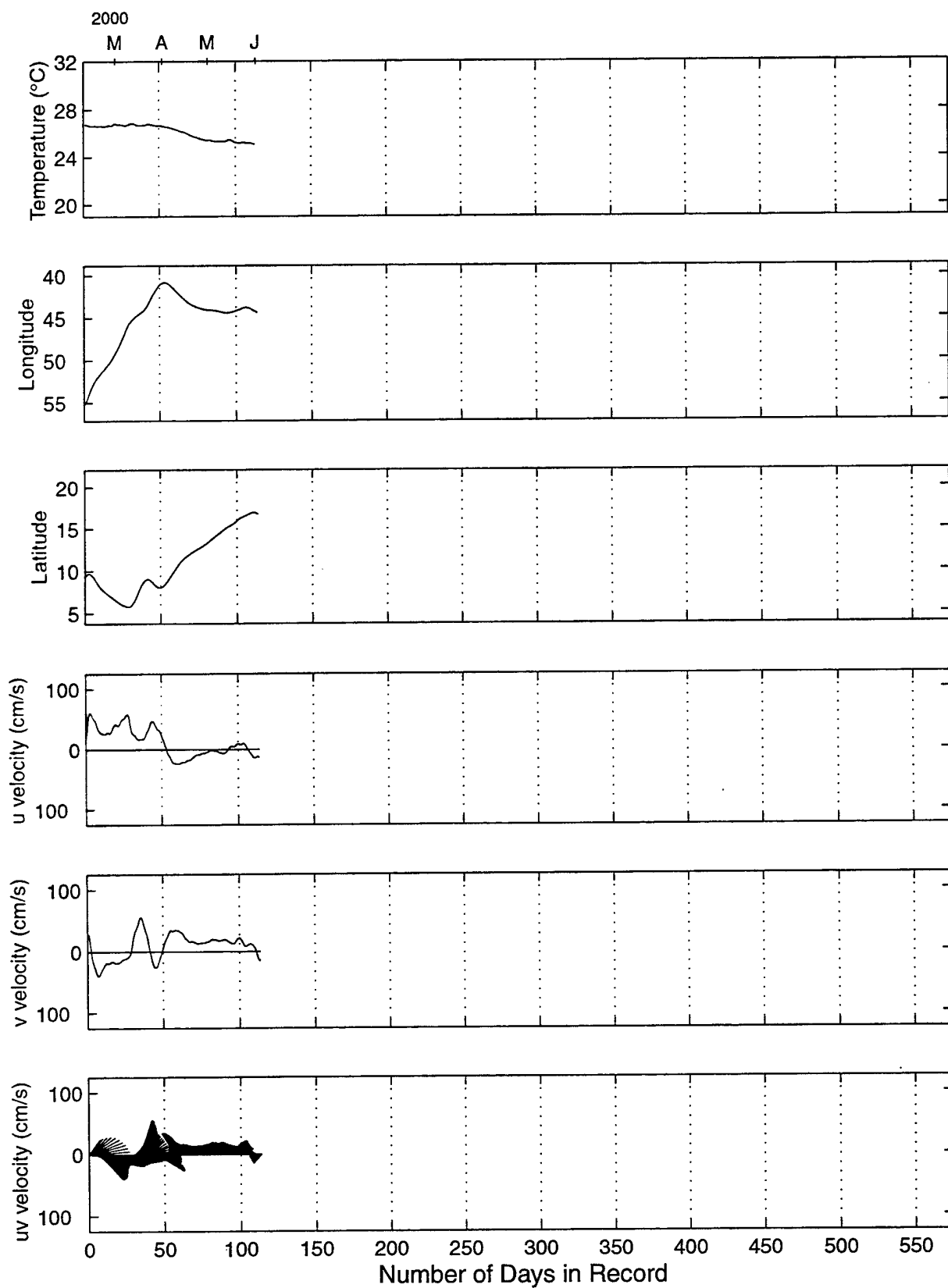


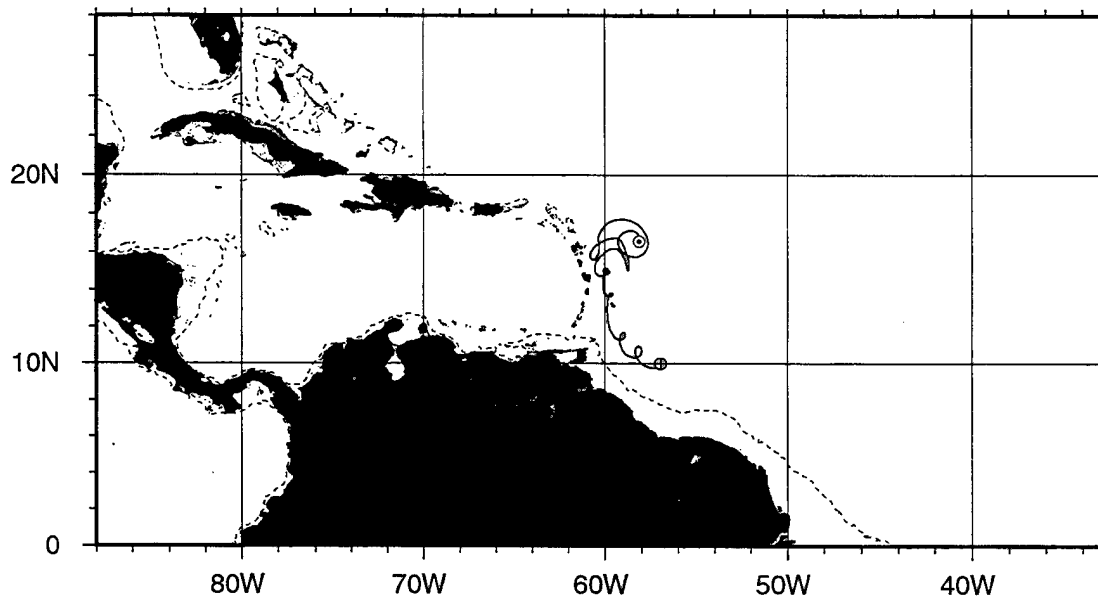
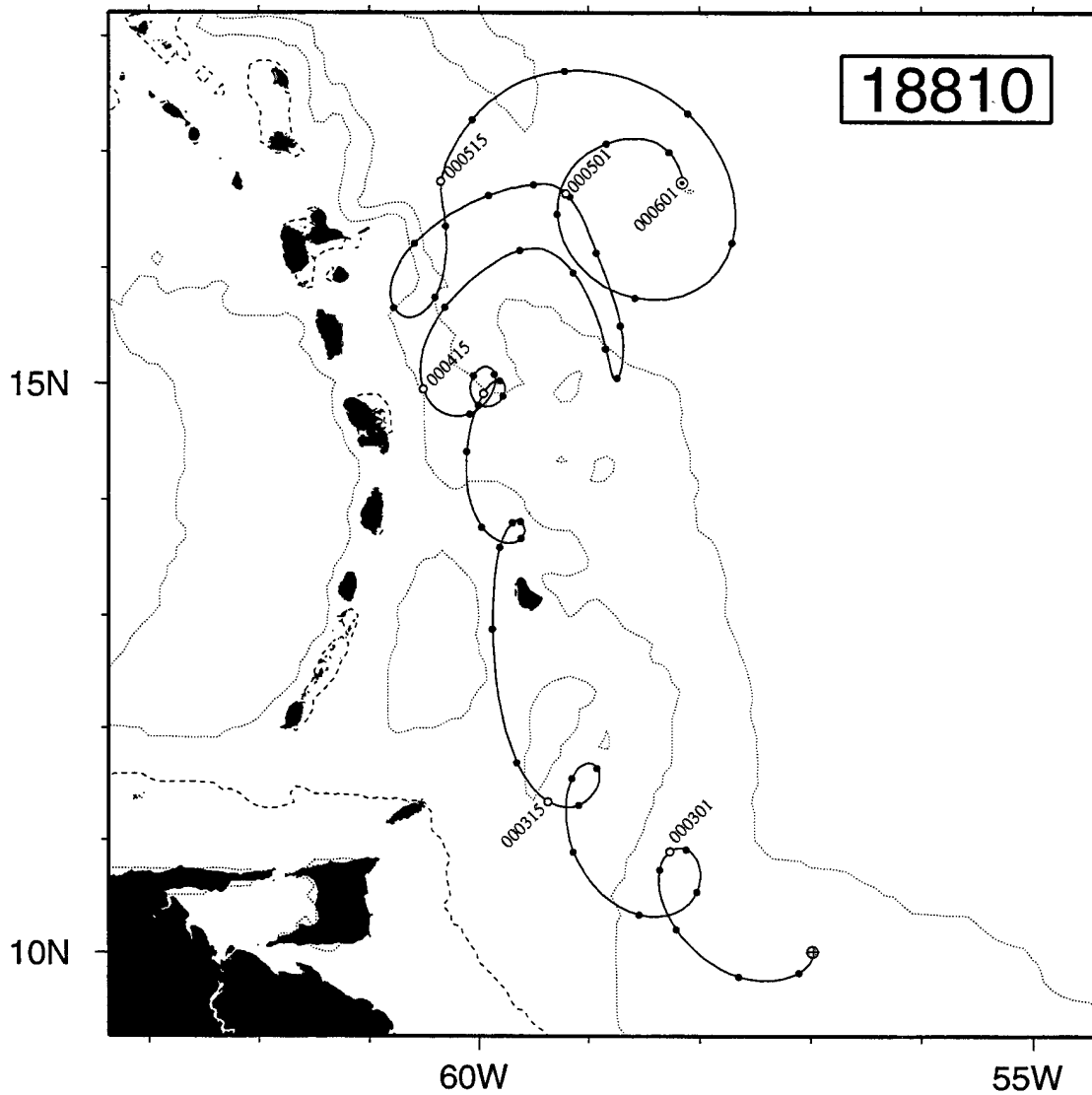
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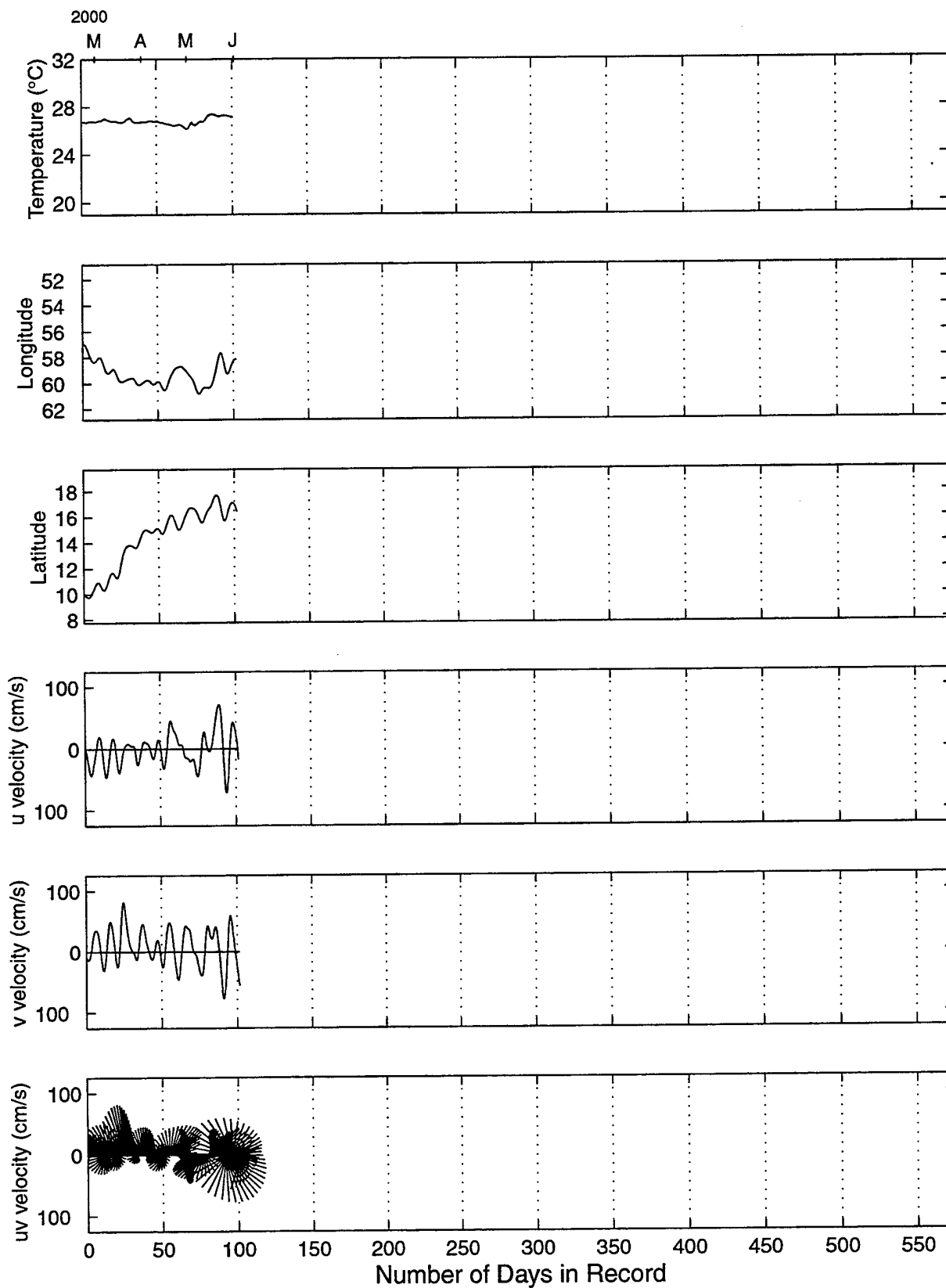


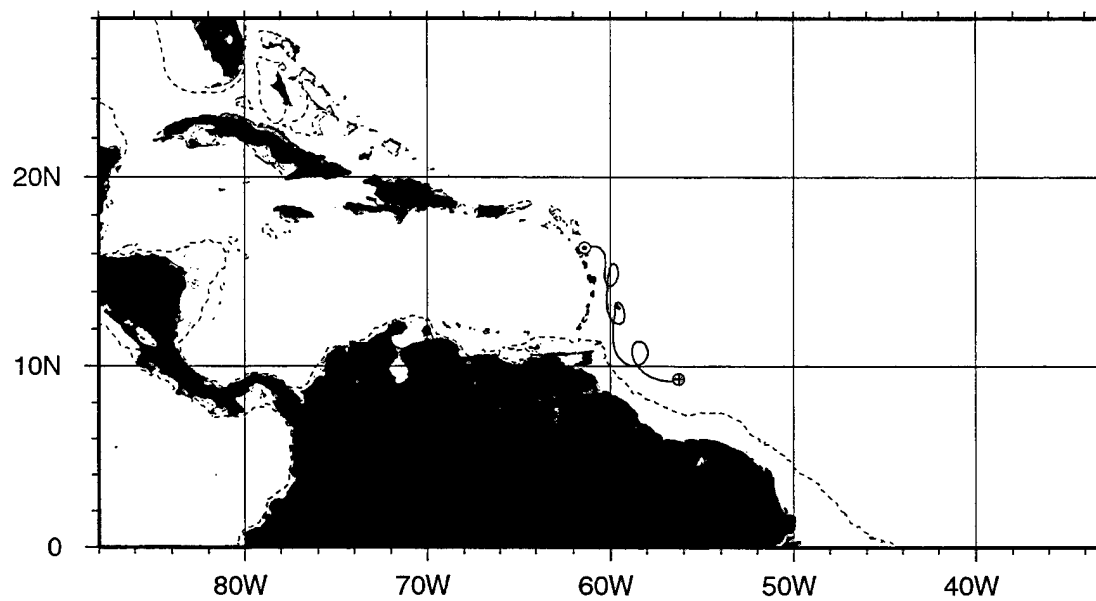
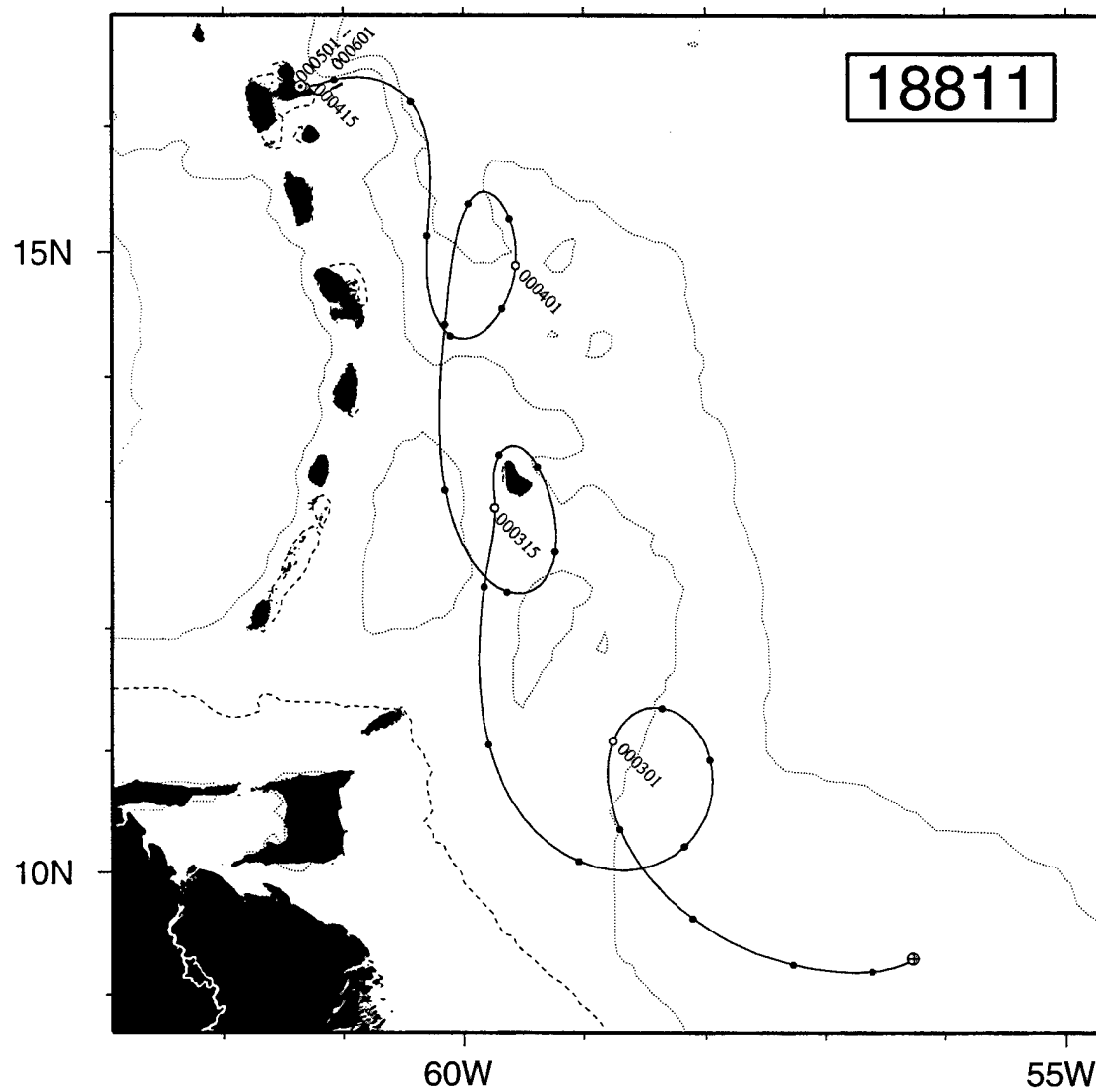
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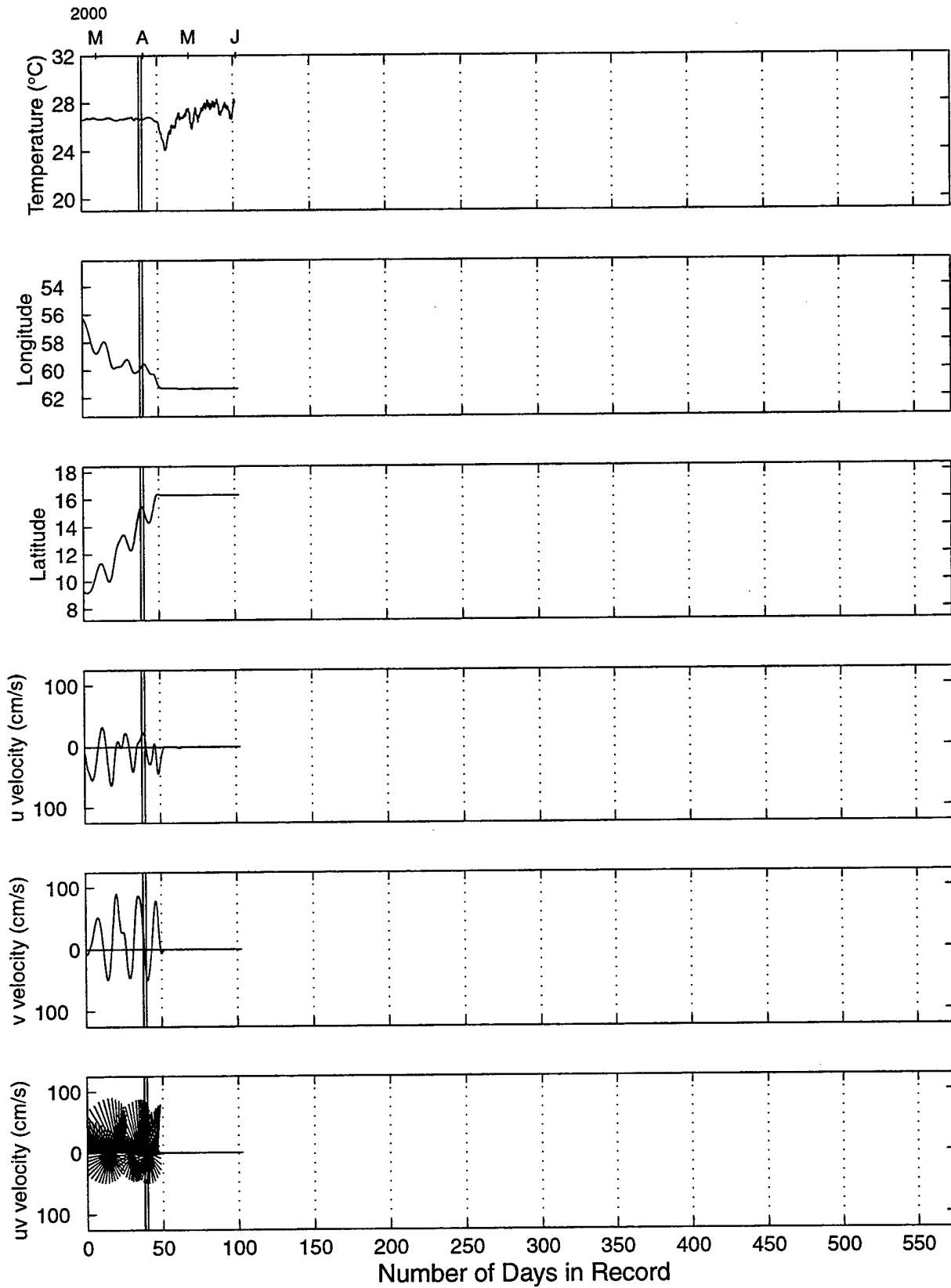


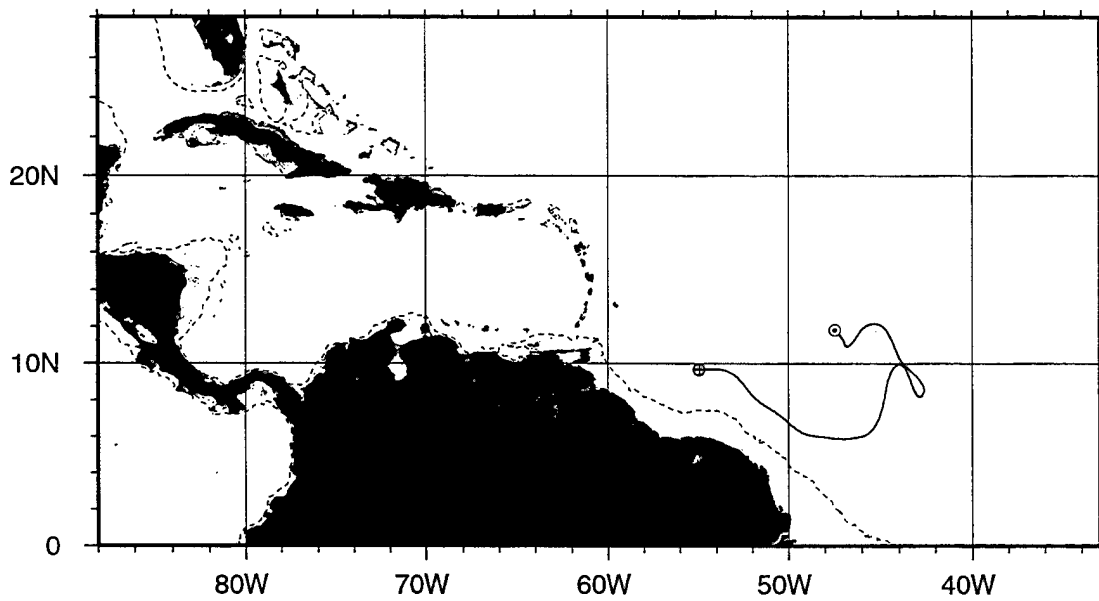
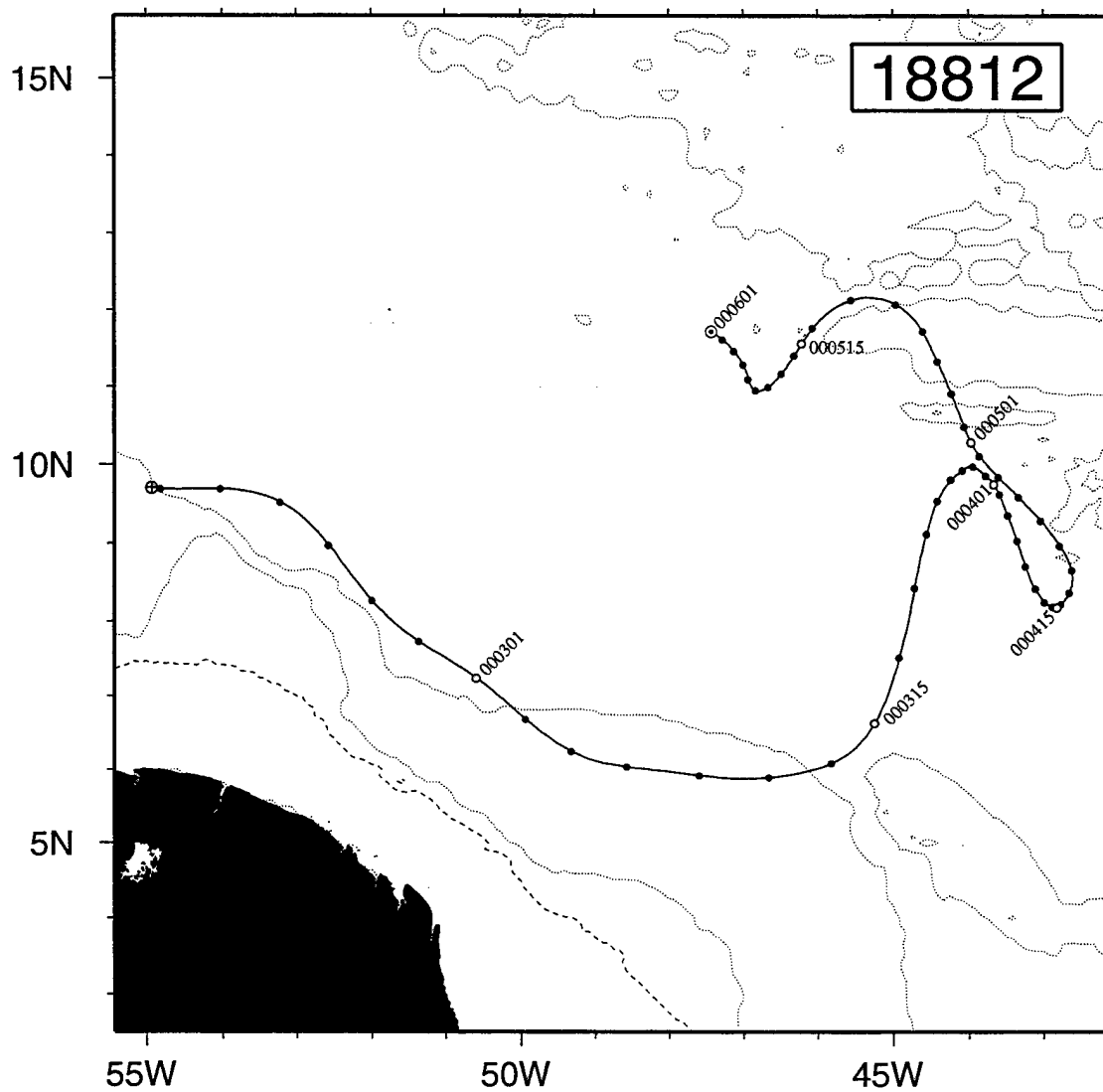
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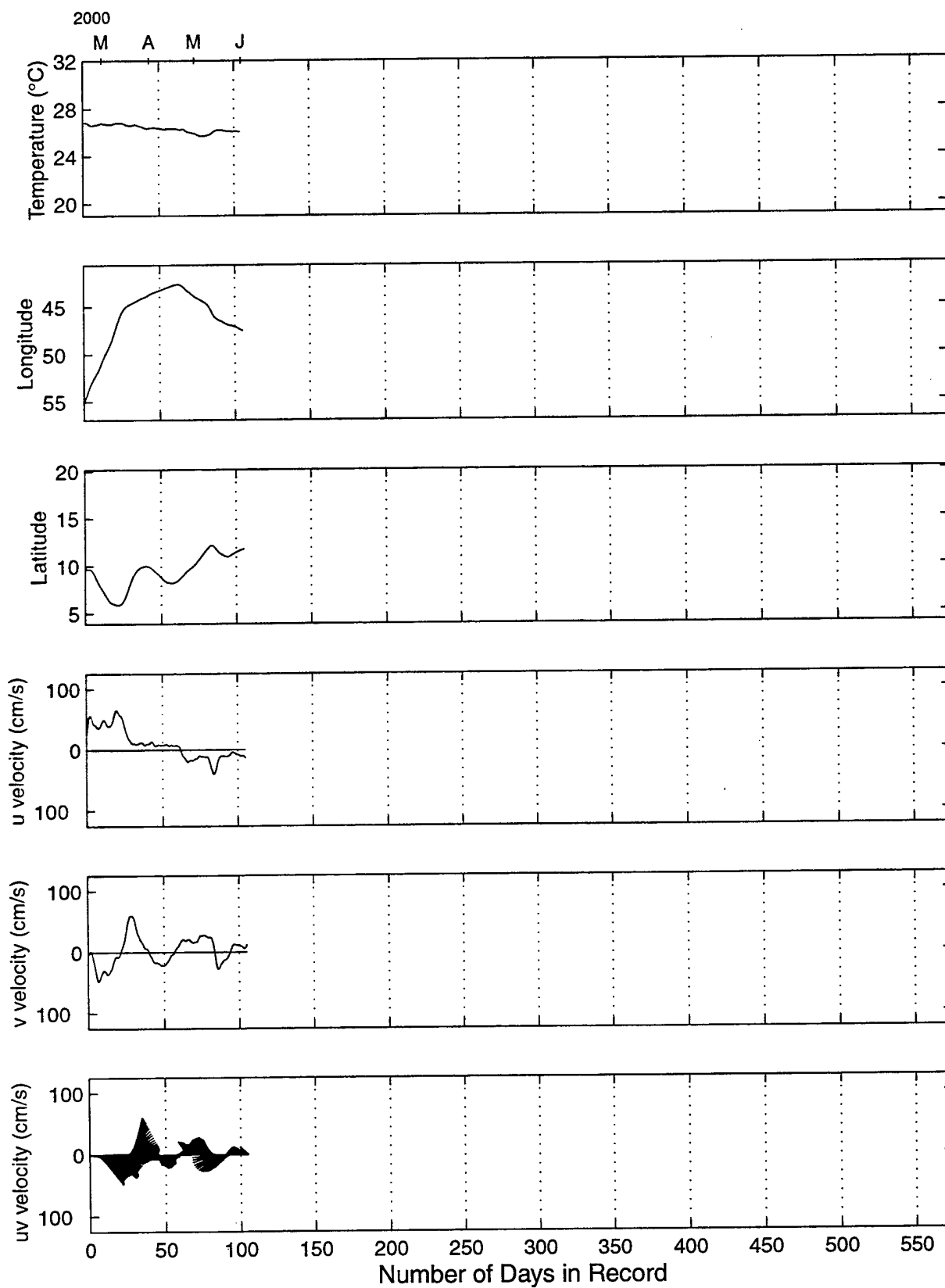


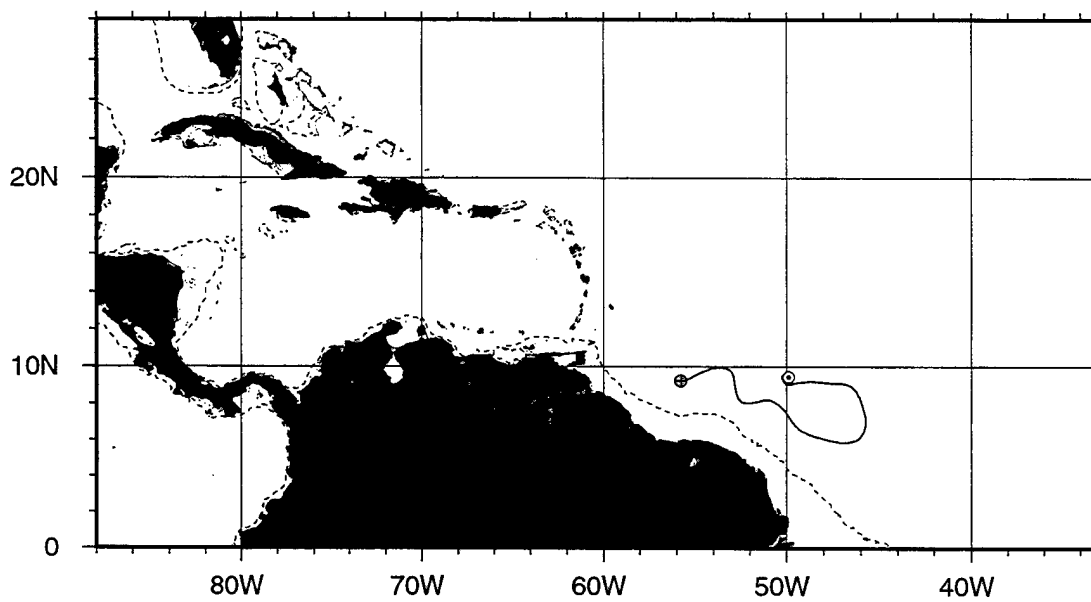
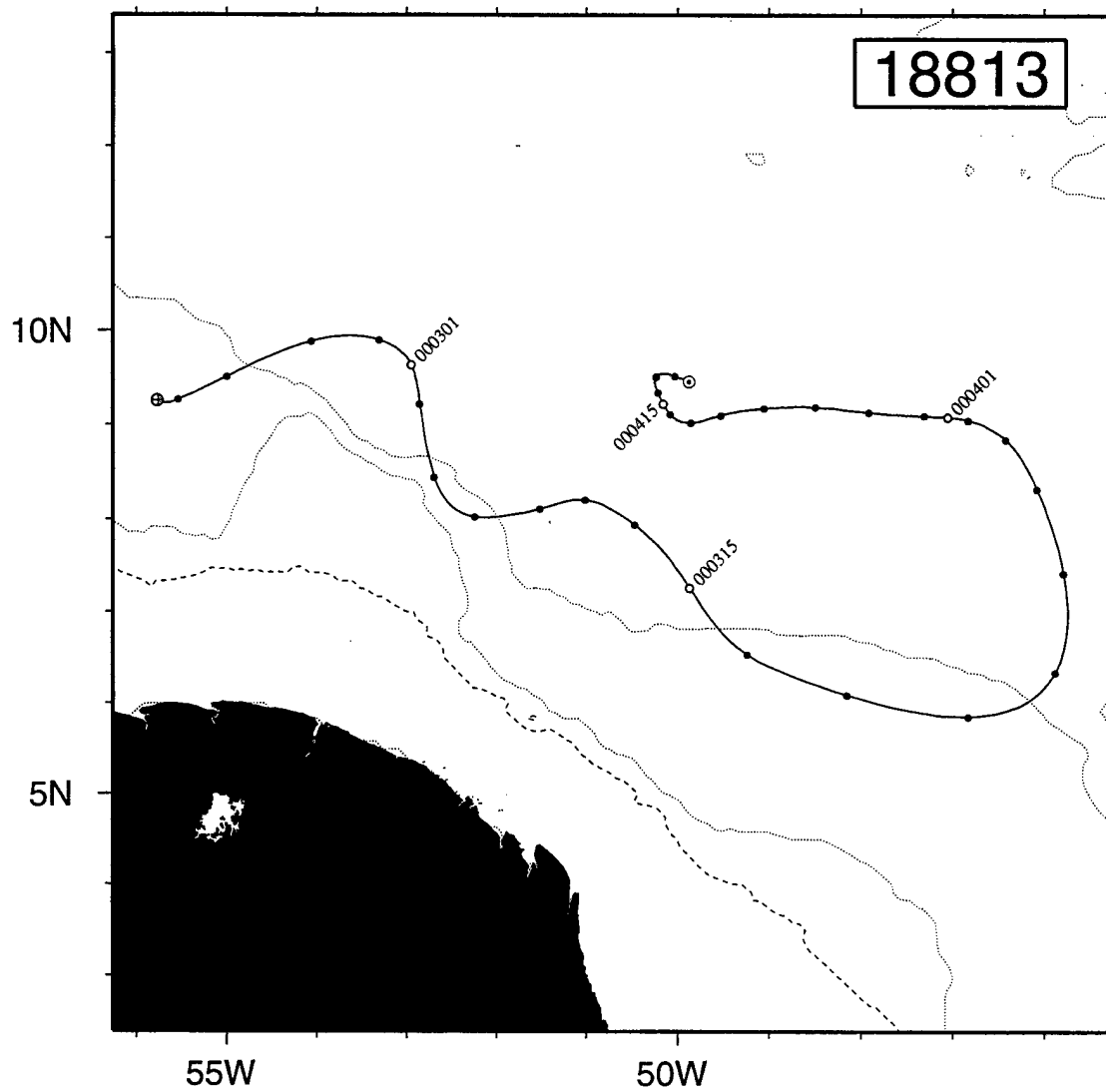
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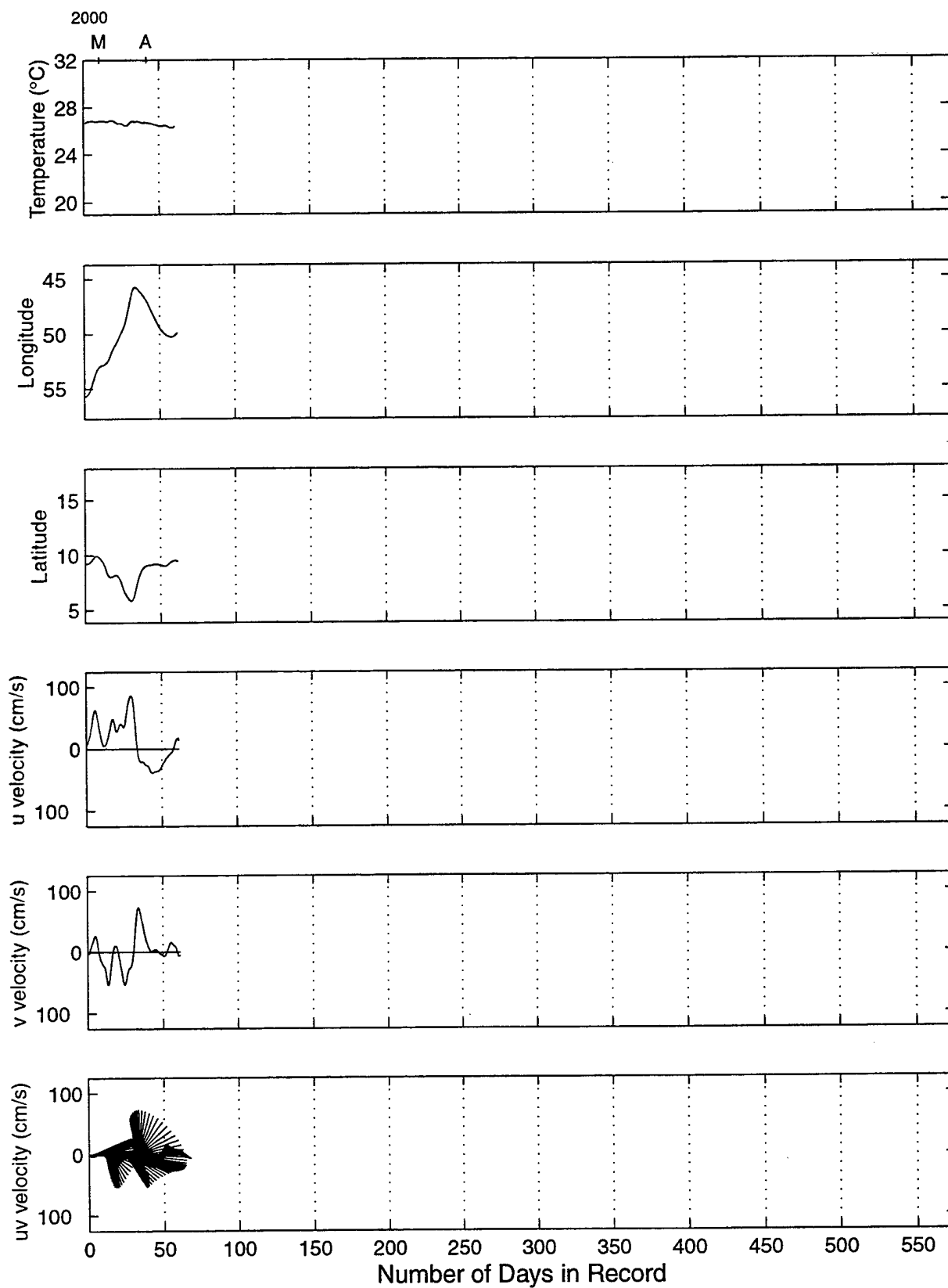


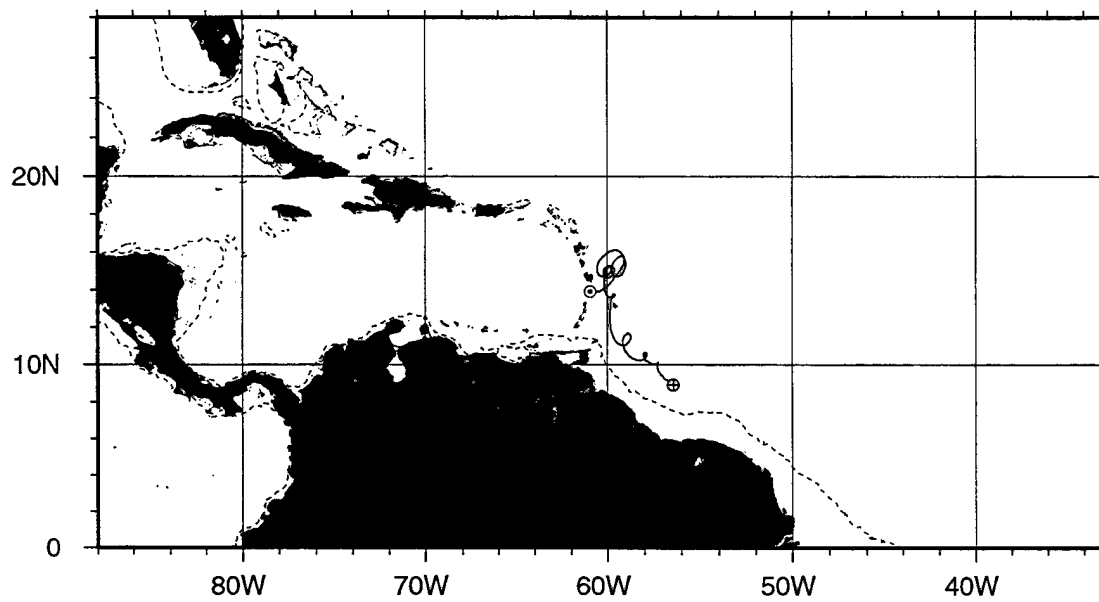
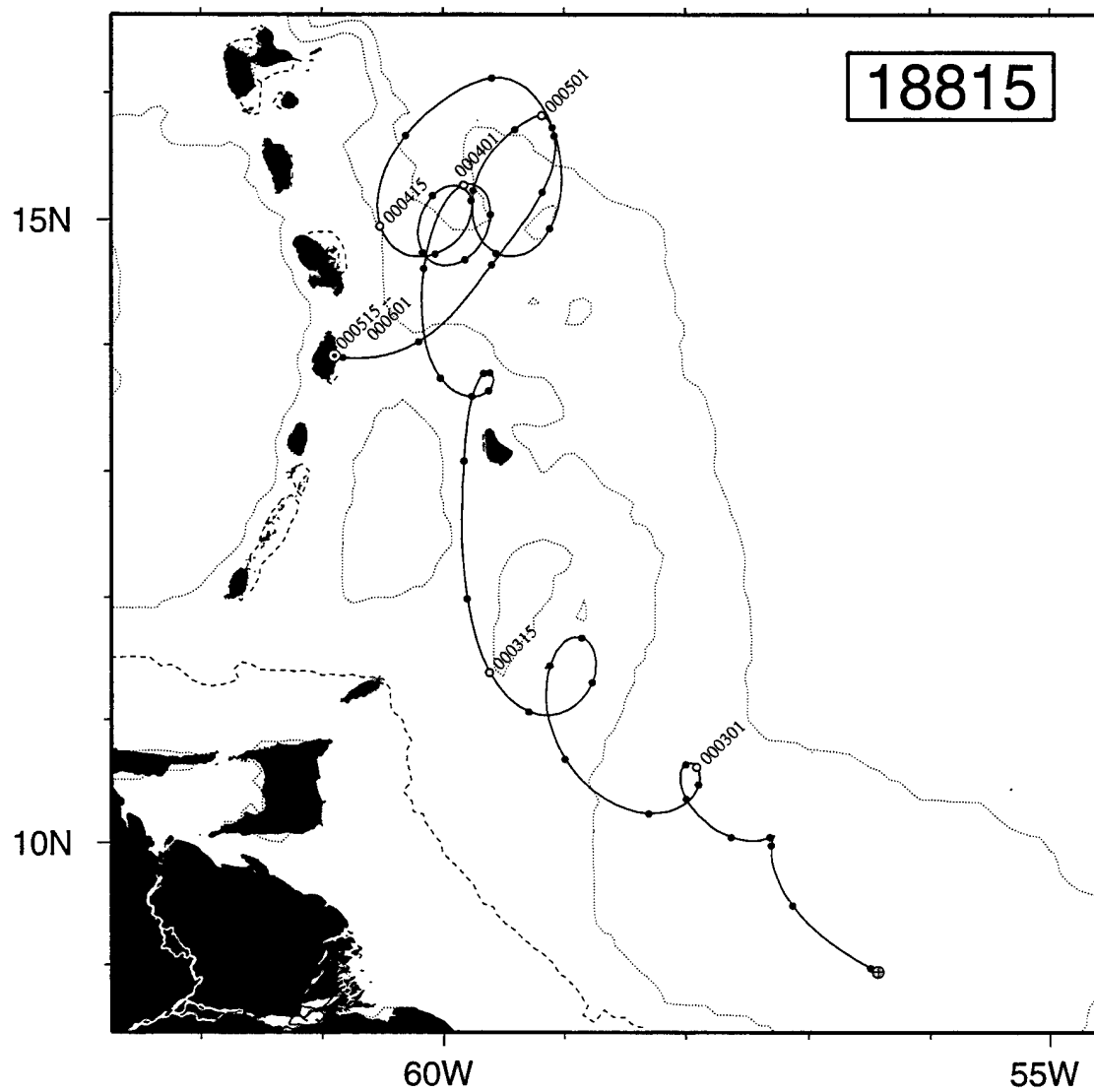
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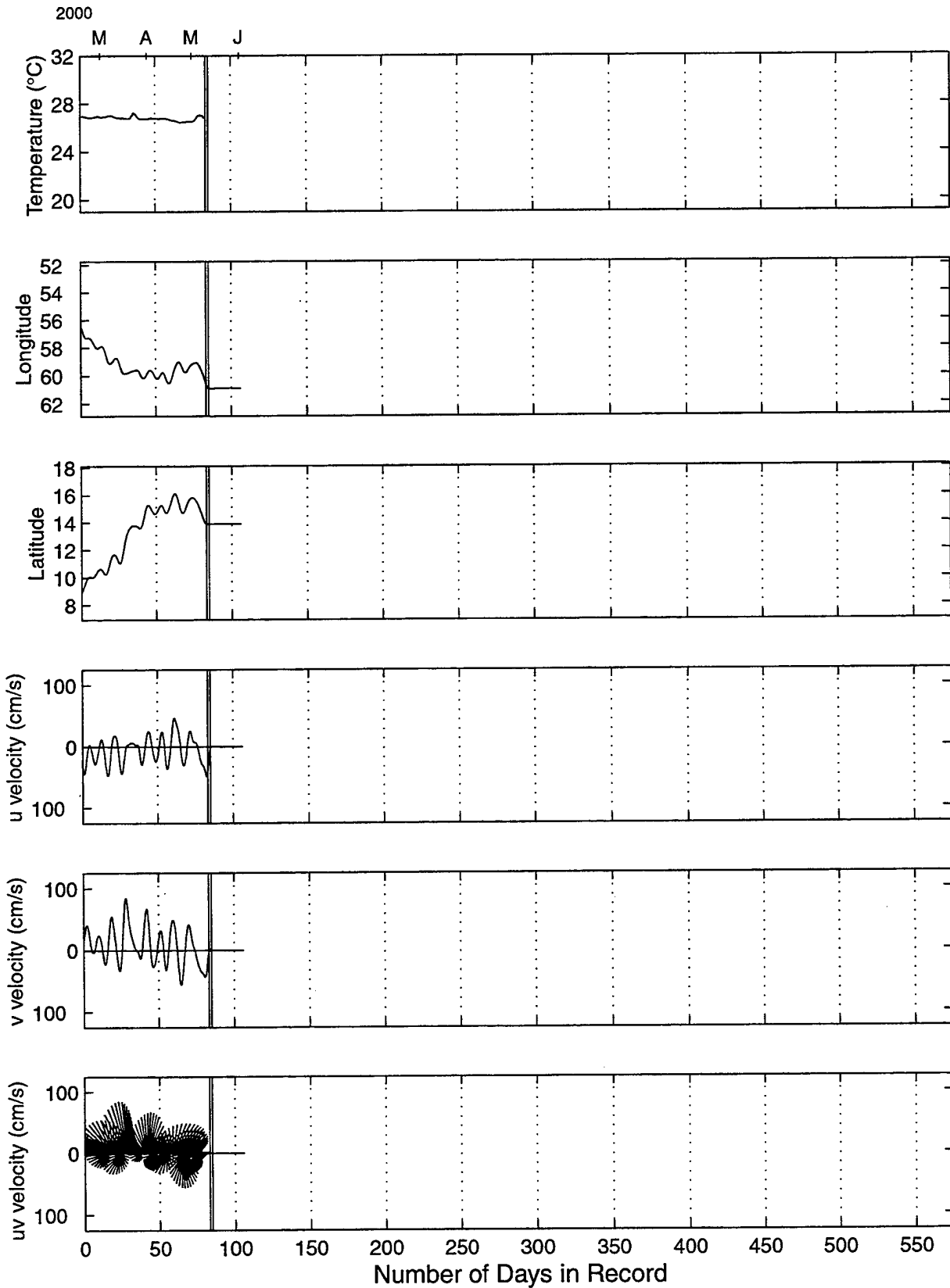


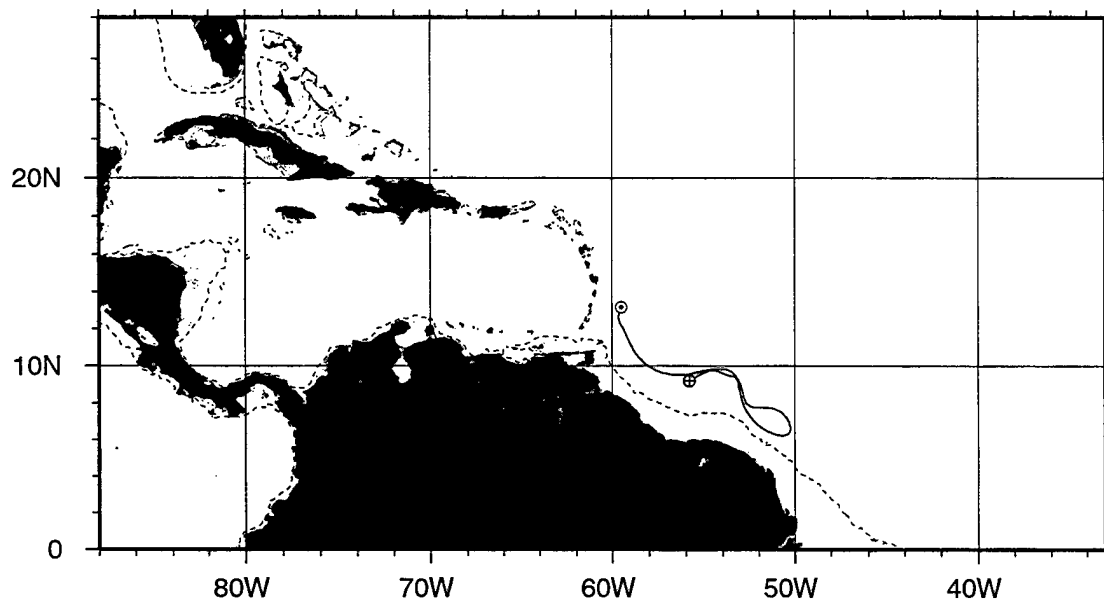
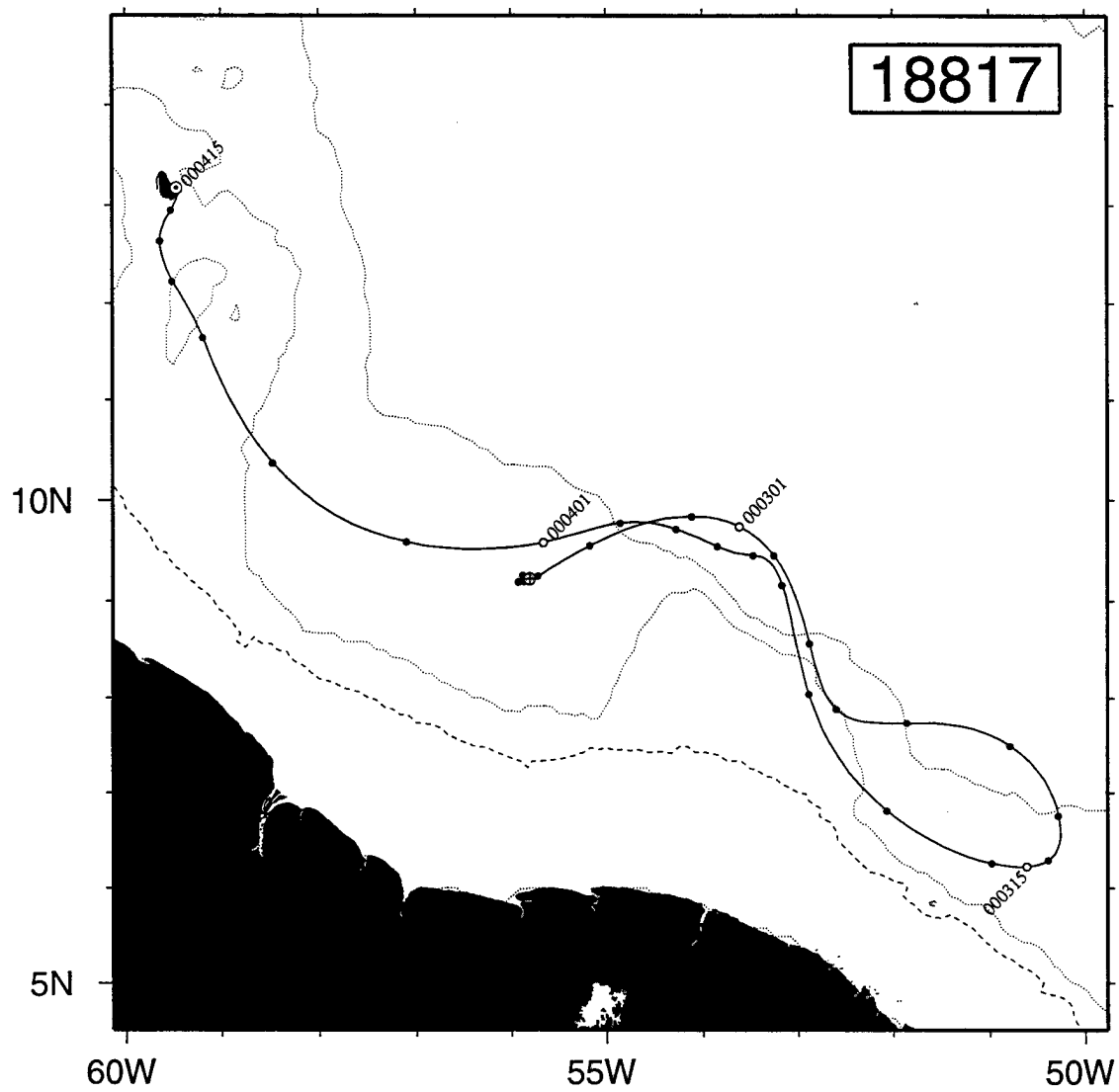
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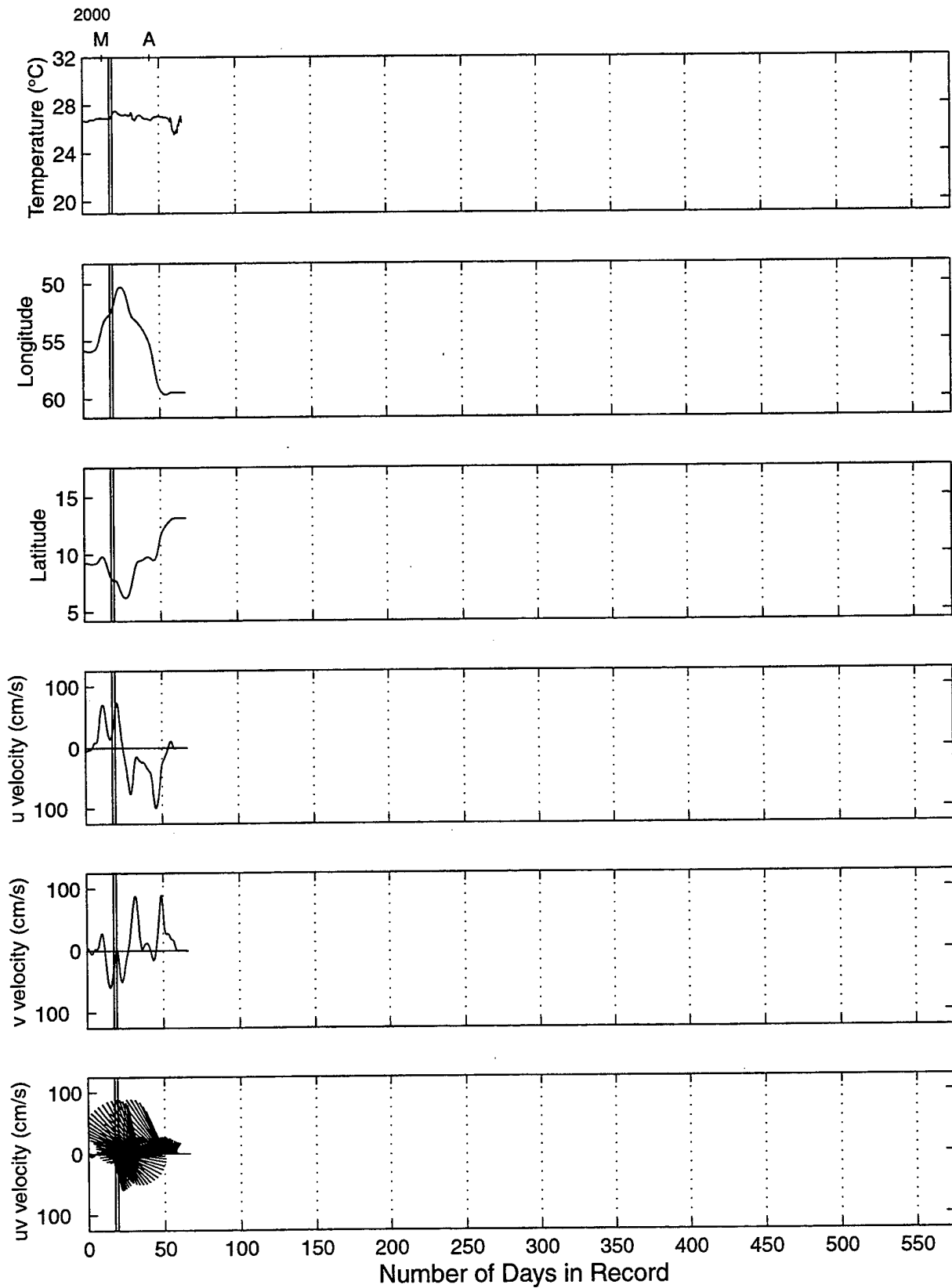


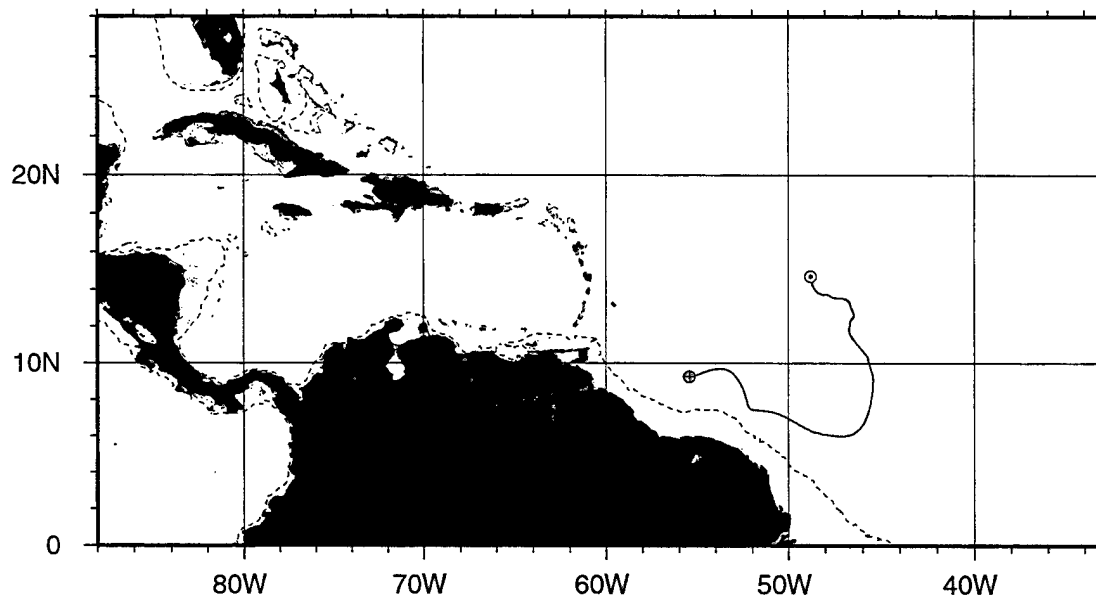
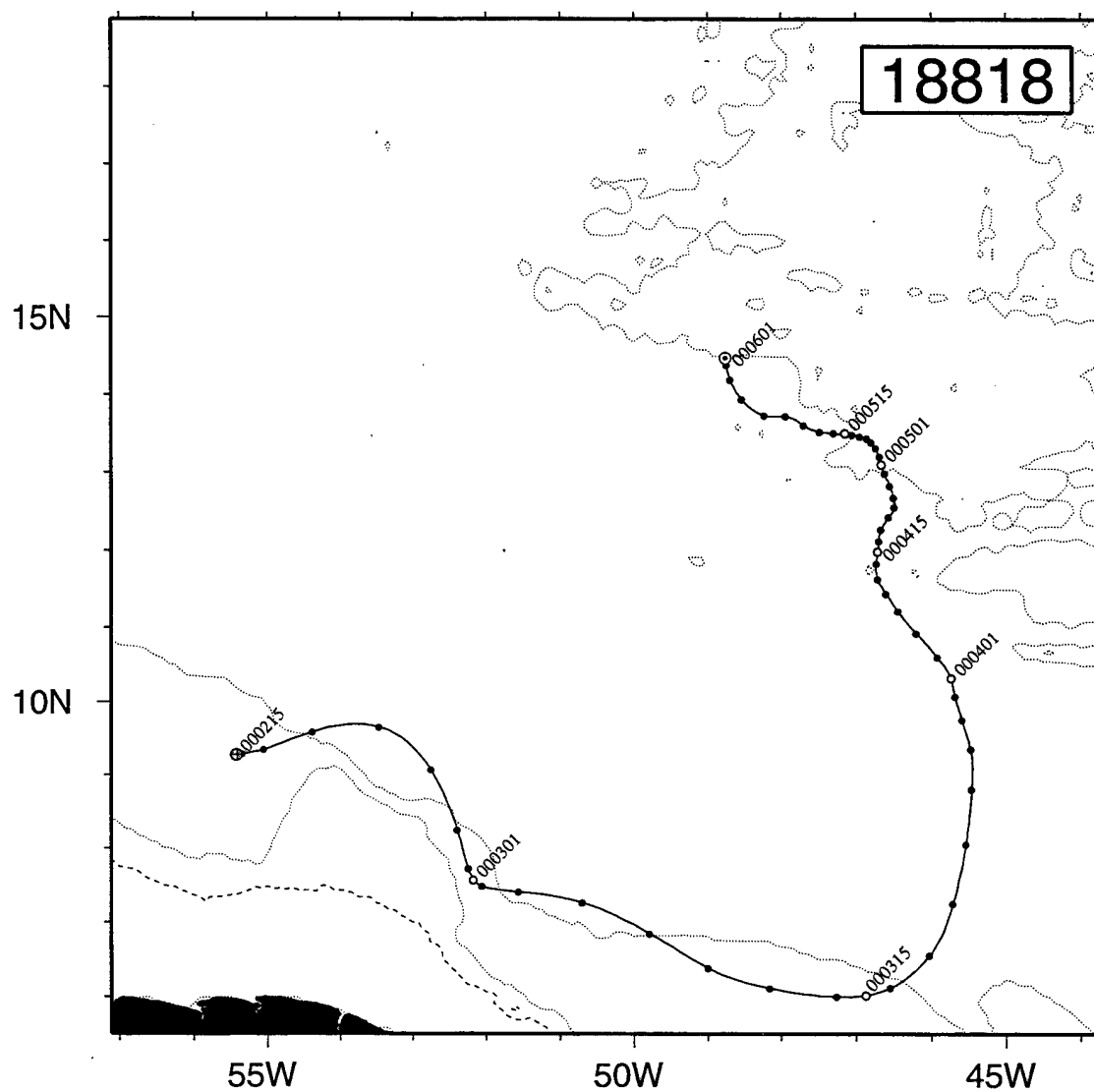
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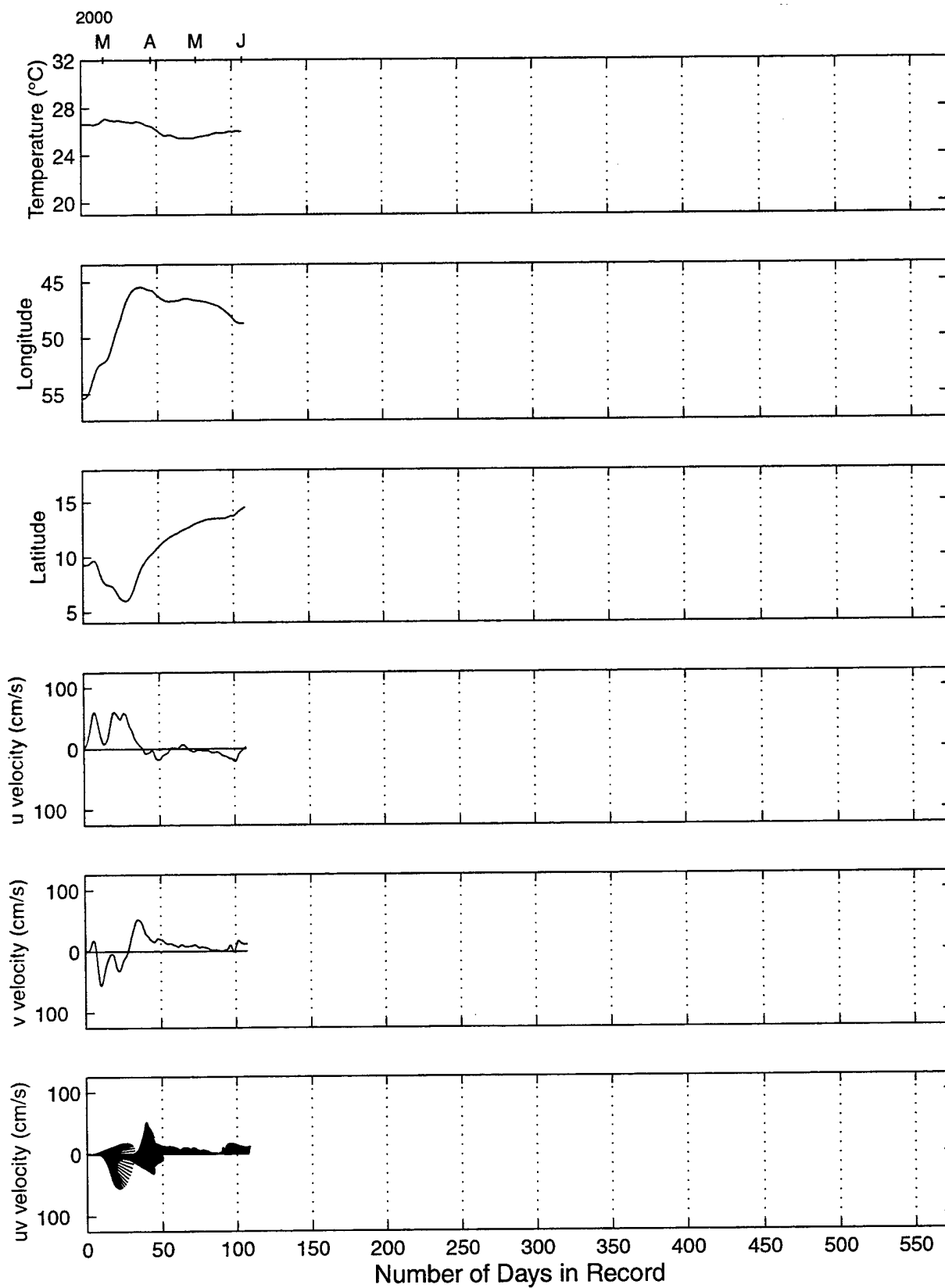


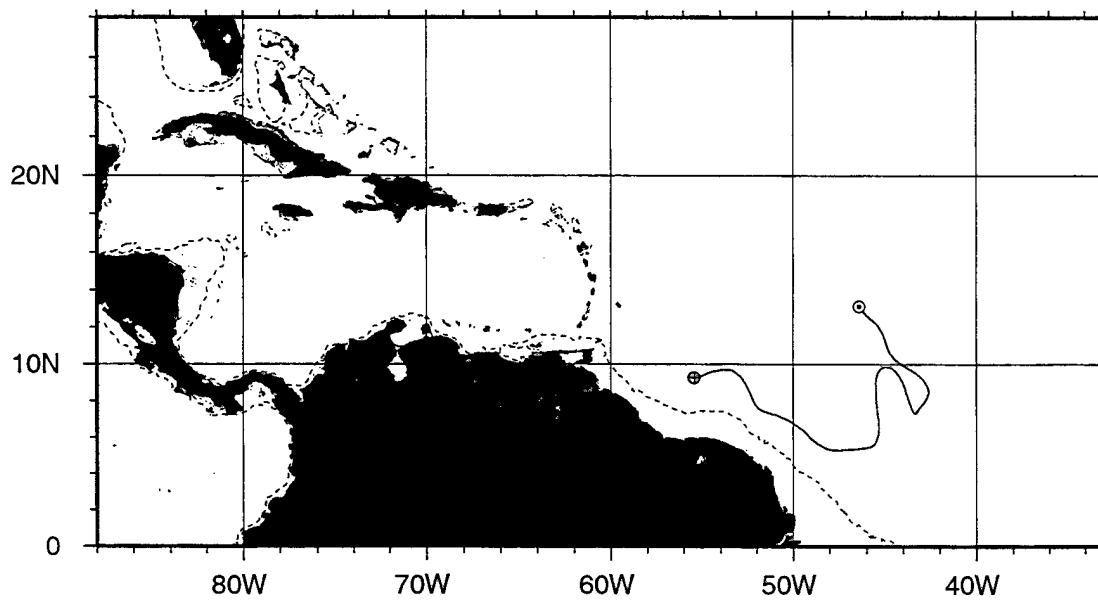
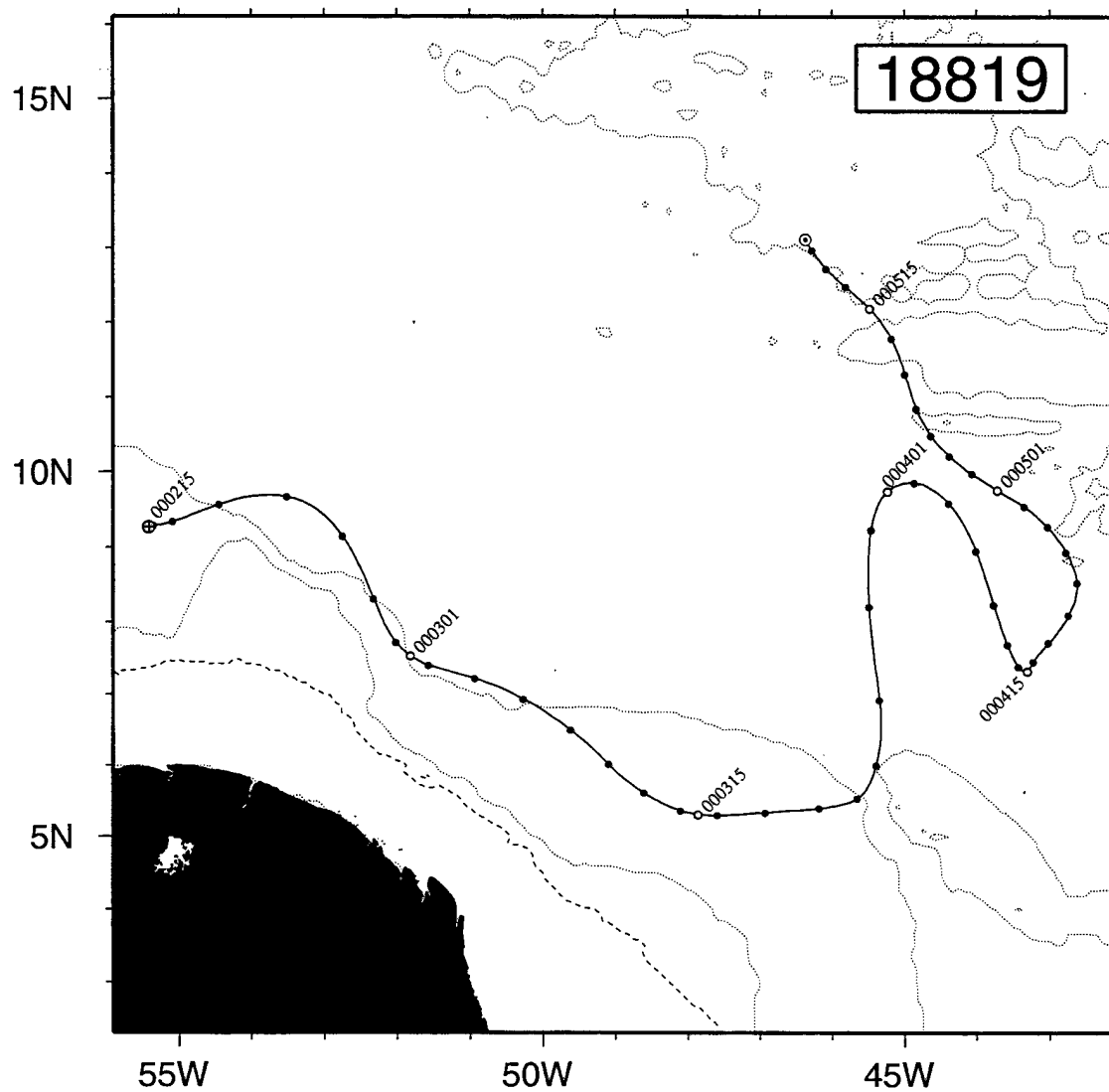
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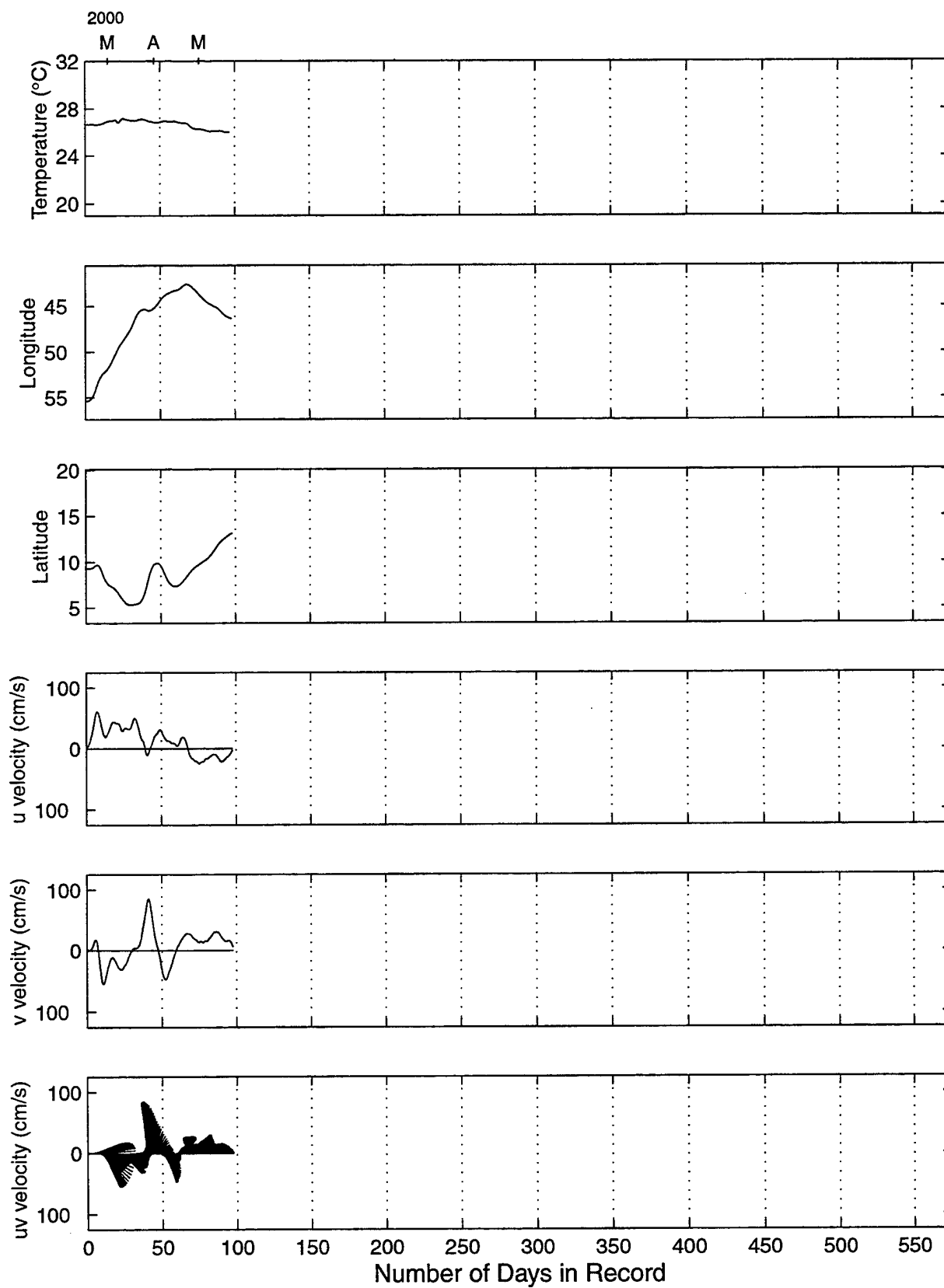


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Appendix D:

Surface drifters launched in June 2000.

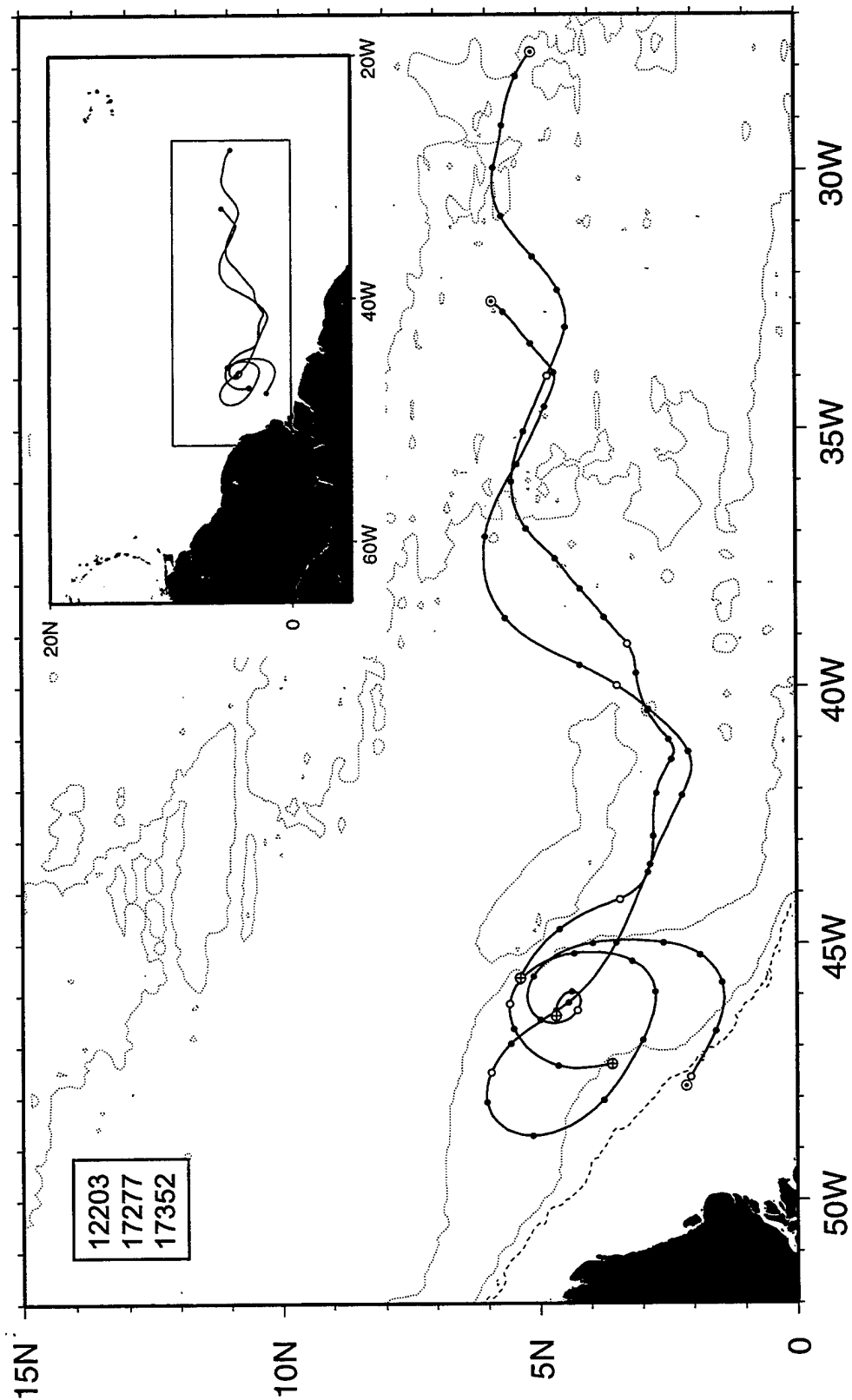
Four surface drifters were launched during the NBC Rings Experiment mooring recovery cruise in June 2000 (Table 3). This appendix presents trajectories and time series measurements from the three drifters that transmitted data. A composite plot showing all drifter trajectories is presented first, followed by individual drifter trajectories and property plots. The presentation format follows that of the previous appendices. Temperature and drogue data for the June 2000 drifters were unavailable for inclusion in this summary.

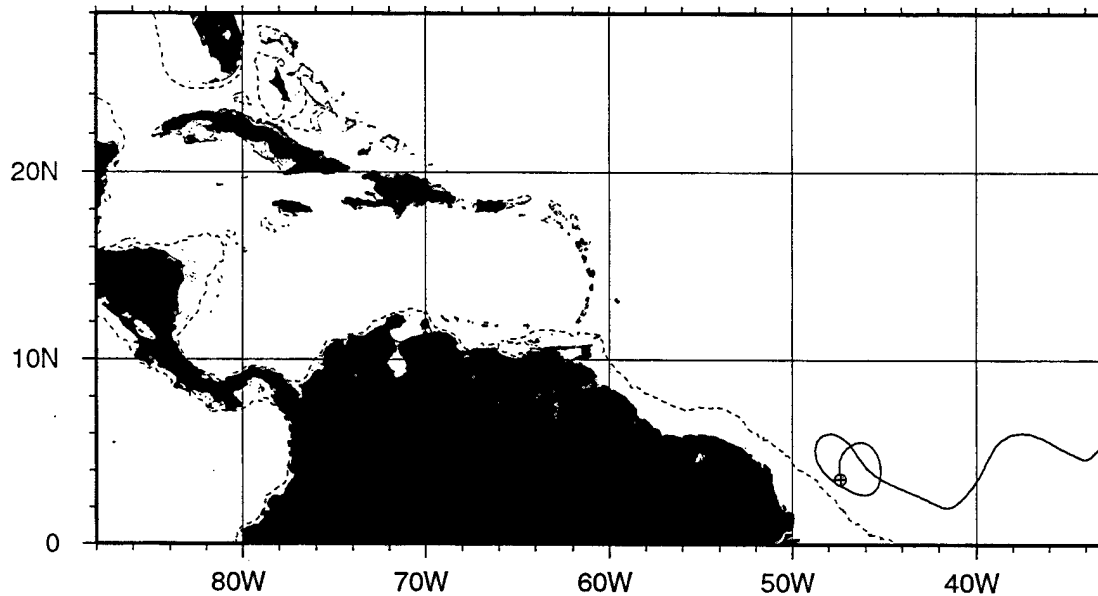
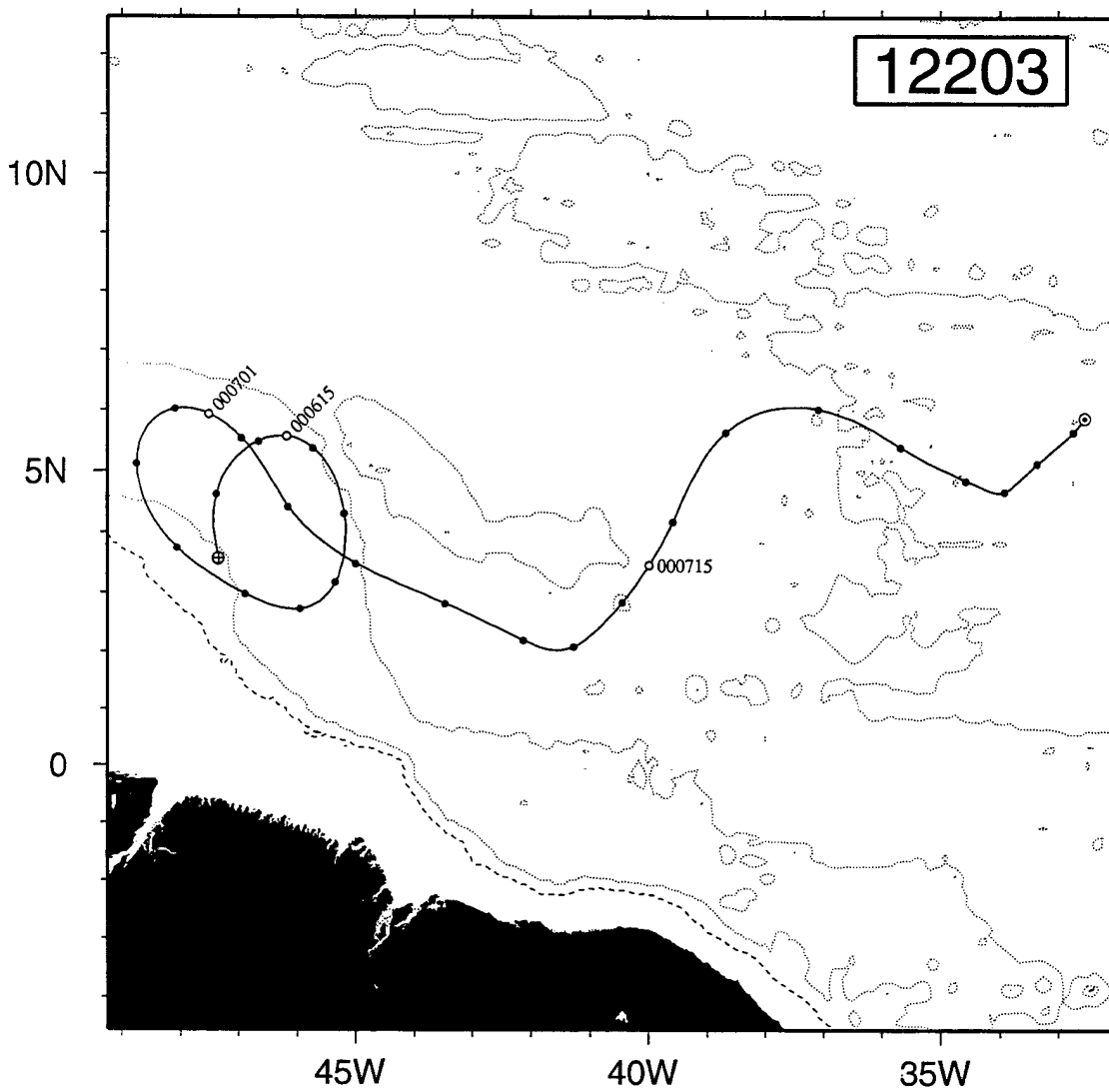
Table 3. Surface drifter summary – launch and end positions, June 2000.

Drifter ID	Launch Date	Launch Position		End Position		Life (days)
		Lon.	Lat.	Lon.	Lat.	
12203	000610	-47.342	3.581	-32.540	5.876	52*
17277	000610	-46.410	4.670	-47.777	2.134	22
17352	000611	-45.670	5.364	-27.721	5.103	52*

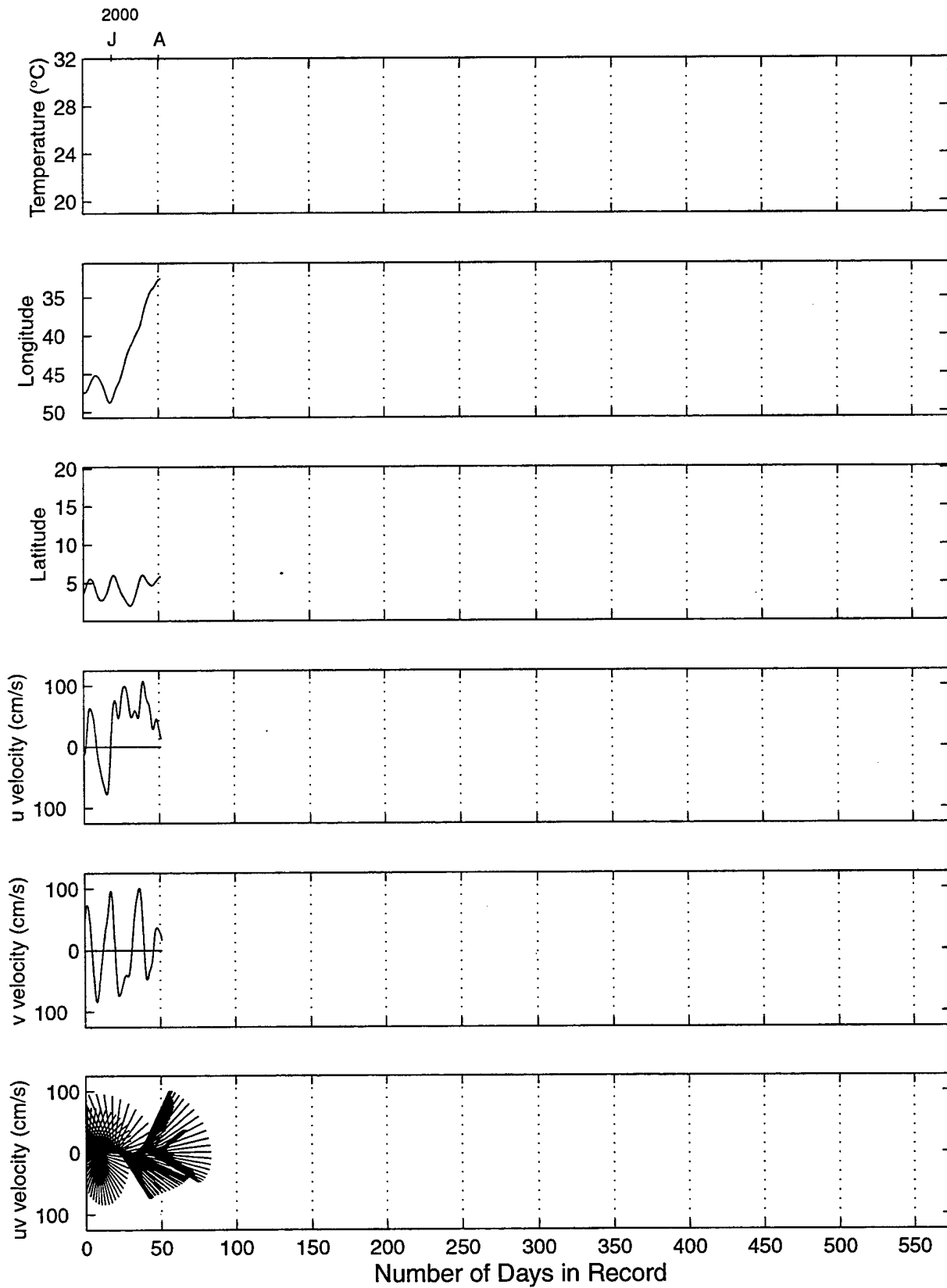
* still alive as of July 31, 2000

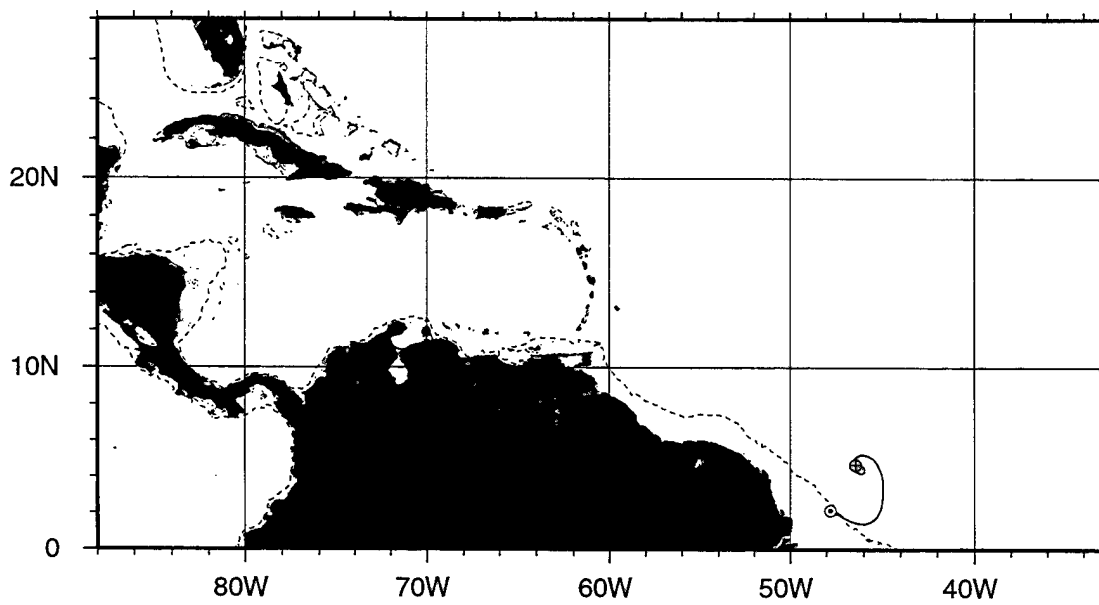
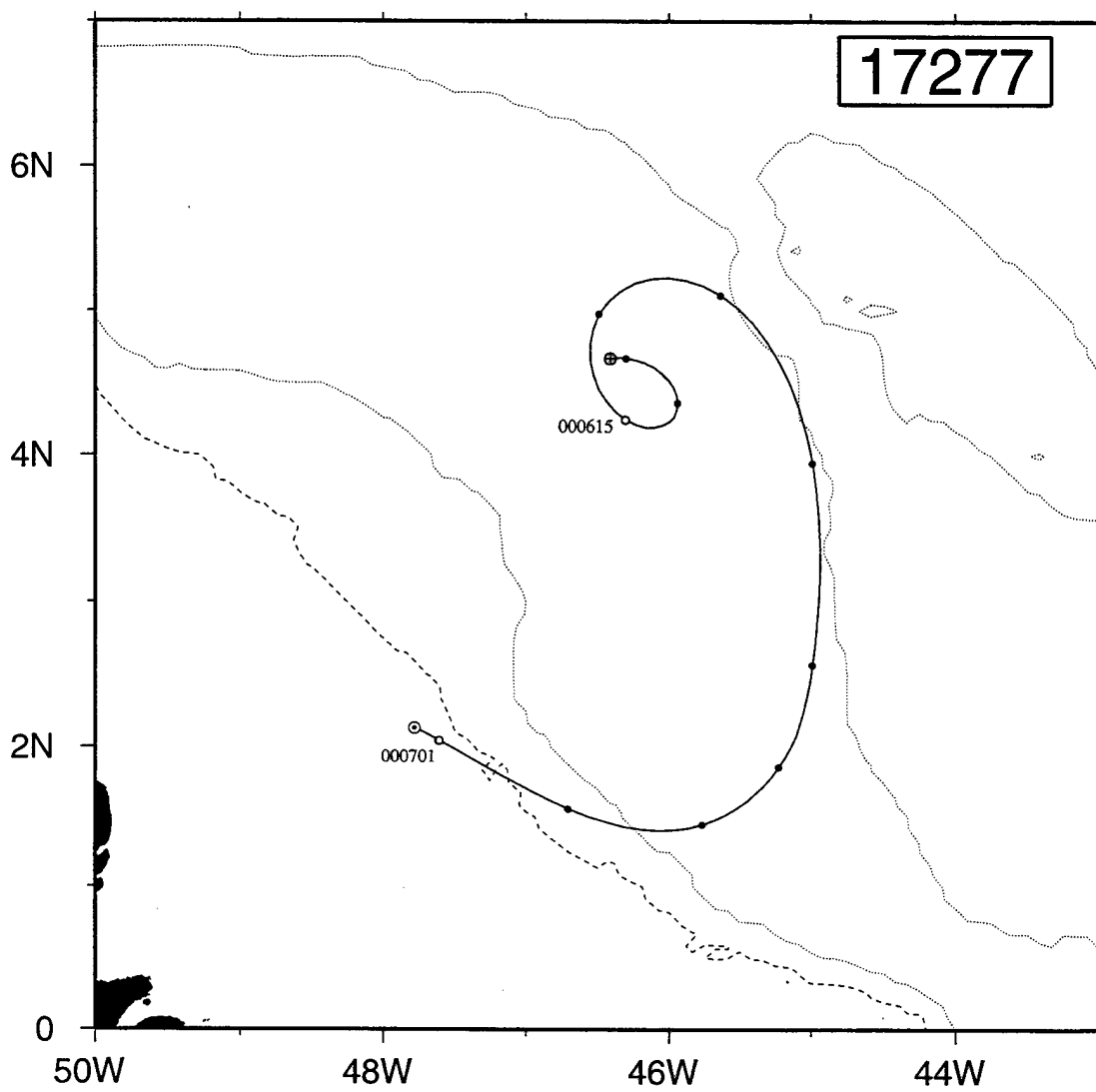
Drifters launched in June 2000



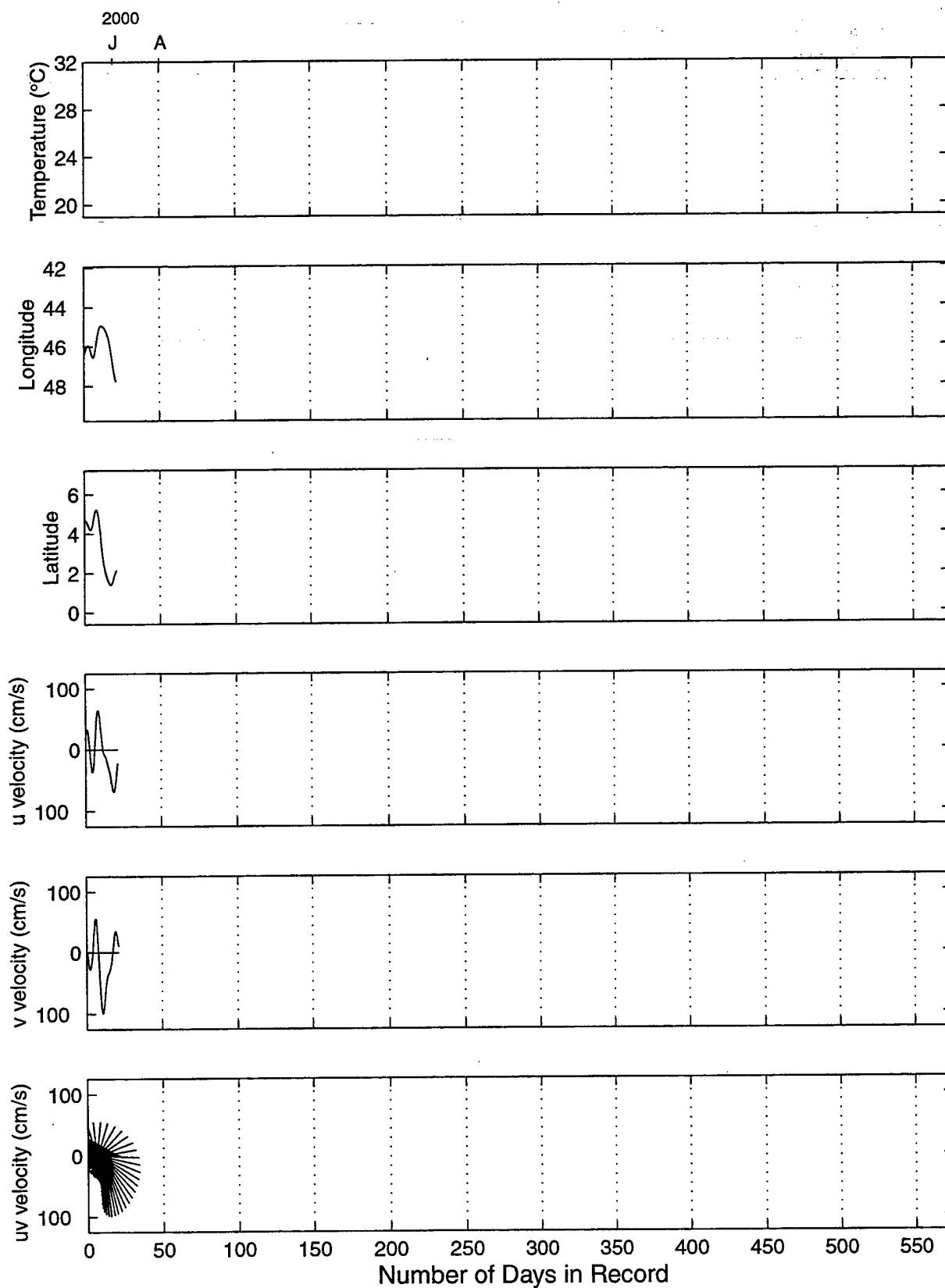


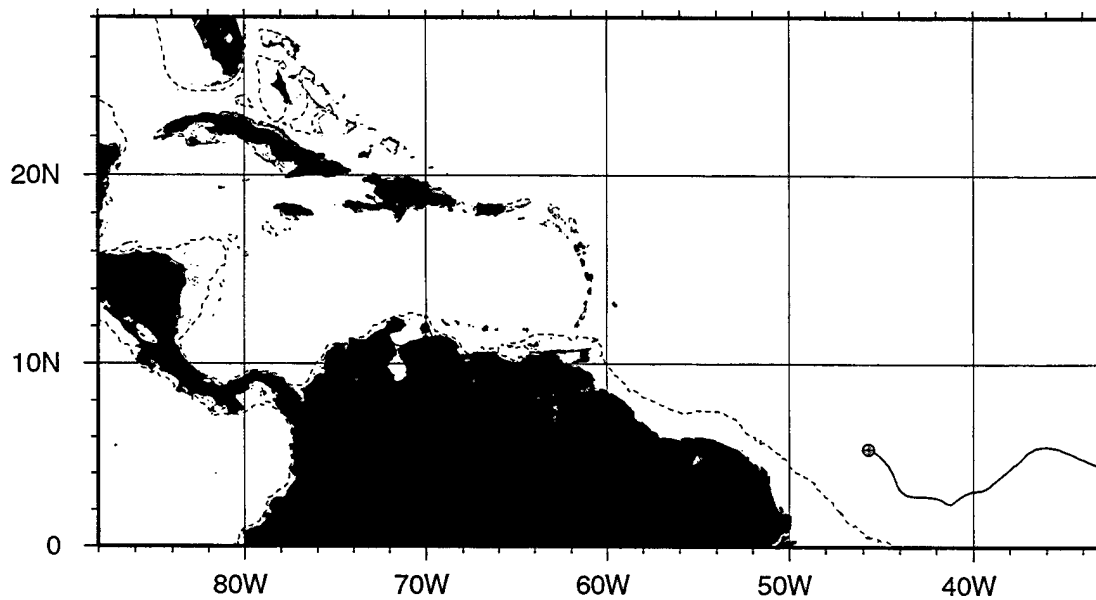
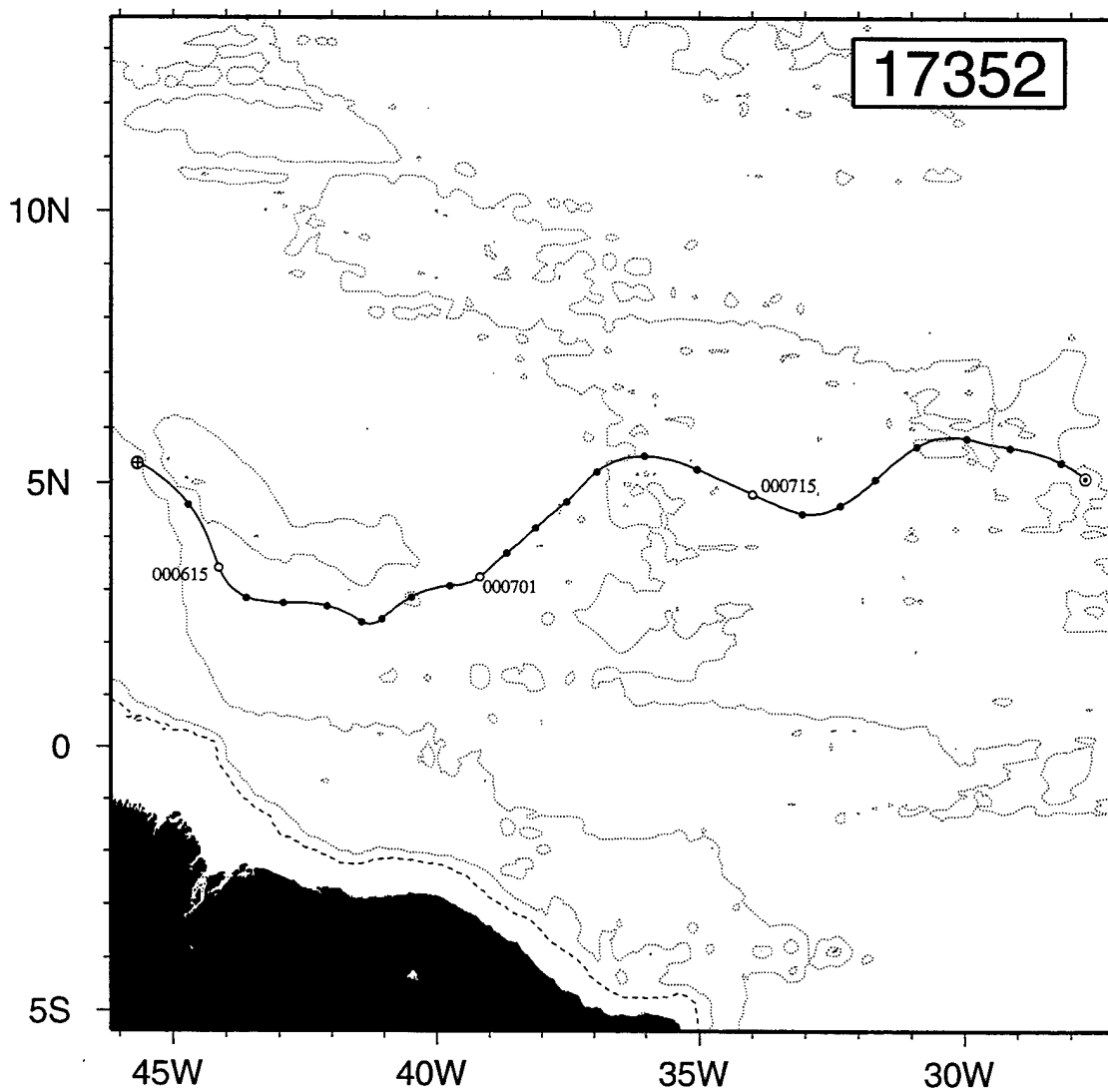
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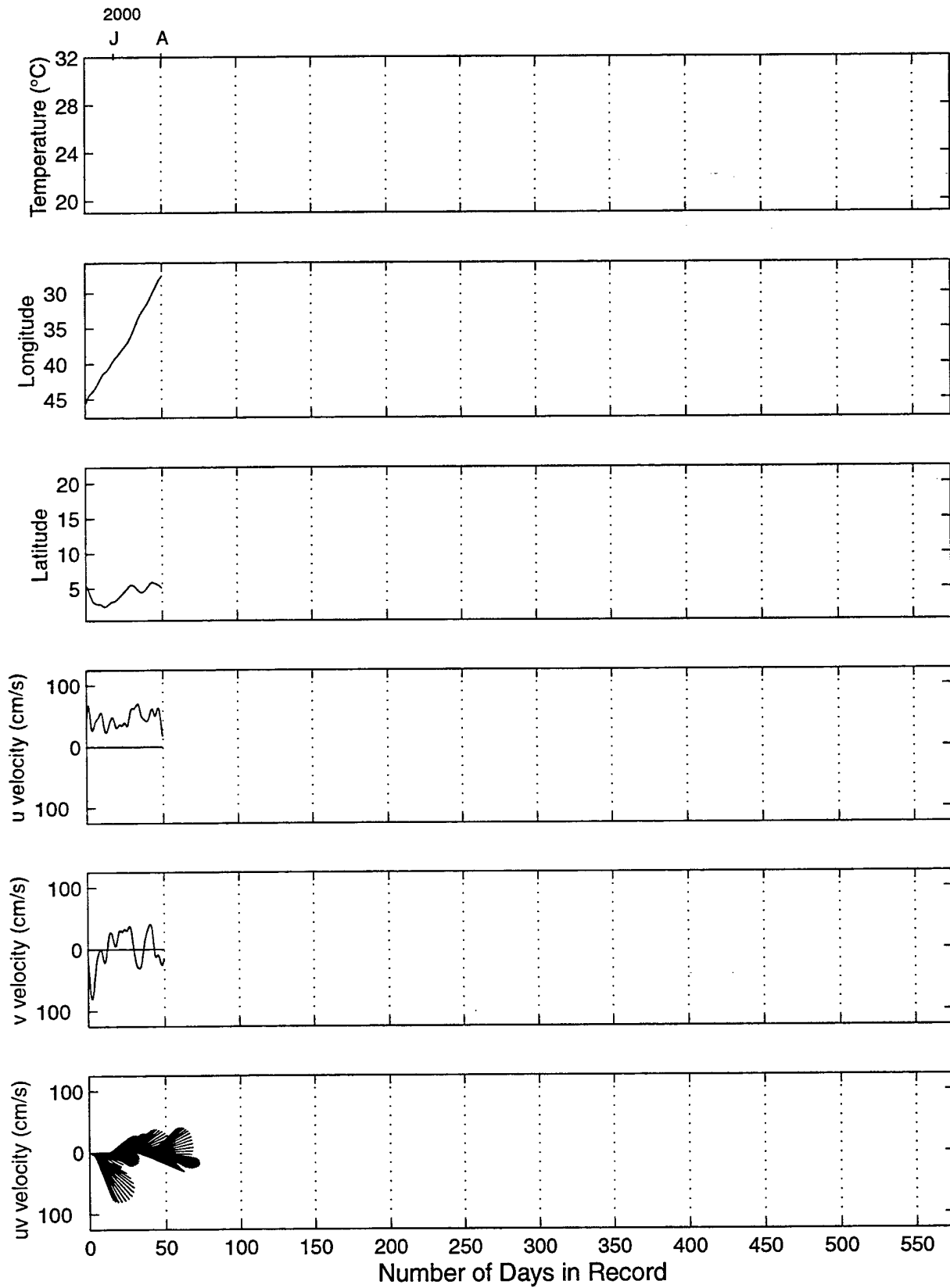


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16. Abstract (Limit: 200 words) This data report summarizes 45 surface drifter trajectories collected between November 1998 and June 2000 as part of the North Brazil Current (NBC) Rings Experiment. NBC rings have been proposed as one of several important mechanisms for the transport of South Atlantic upper-ocean water across the equatorial-tropical gyre boundary and into the North Atlantic subtropical gyre. Such transport is required to complete the meridional overturning cell in the Atlantic forced by the high-latitude production and southward export of North Atlantic Deep Water. The goal of this program is to obtain, for the first time, comprehensive observations of the NBC retroflection, the NBC ring formation process, and the physical structure and properties of NBC rings as they translate northwestward along the low-latitude western boundary. A total of 45 drifters were deployed. Twenty-four of these looped anticyclonically within the five rings identified during this experiment. Seven of the looping ring drifters entered the Caribbean, while the rest moved northward along the eastern flank of the Lesser Antilles.			
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